THE THEORY AND PRACTICE

OF

TECHNICAL WRITING

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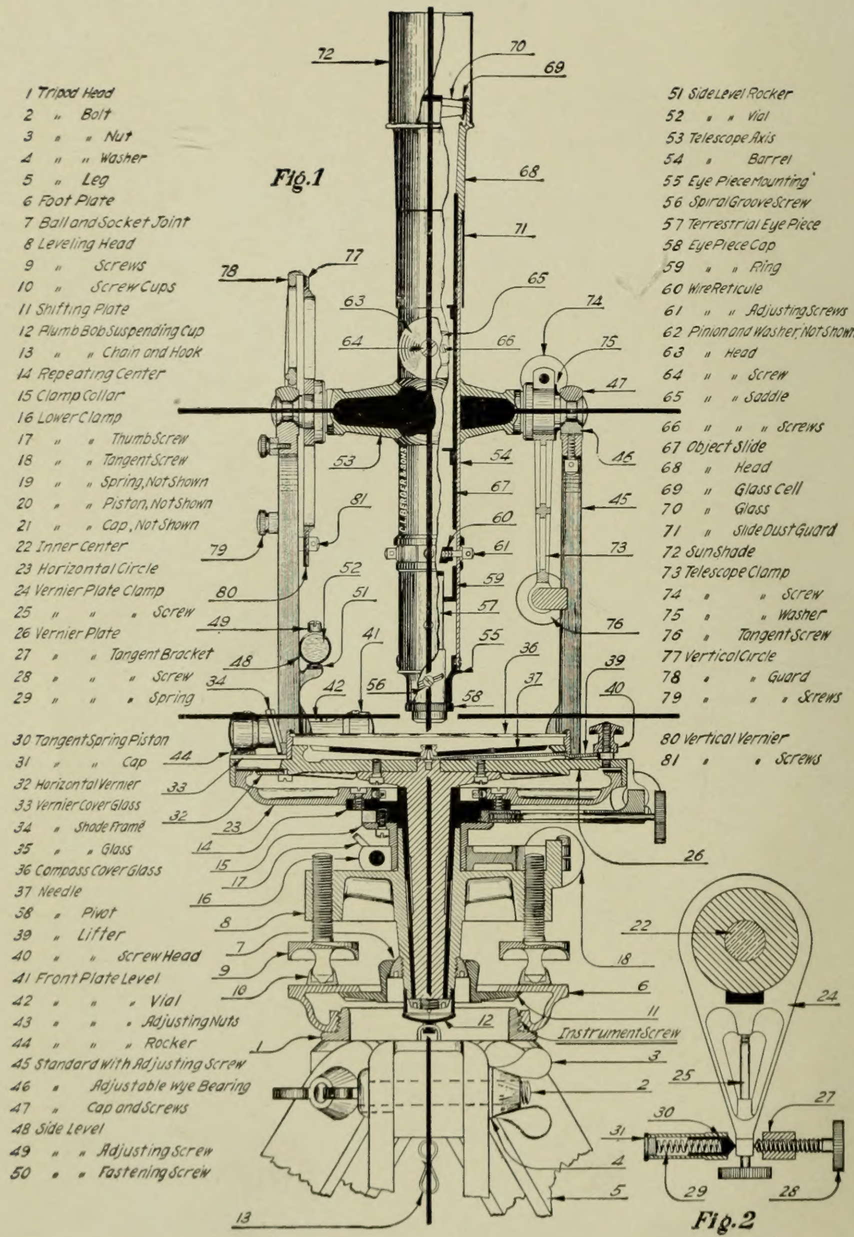

Cross Section of the Berger Transit.

The heavily drawn center line and the two parallel lines drawn at right angles to it in the above cut indicate conditions required in a perfectly adjusted transit.

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BY

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PREFACE

EVERY engineer who has given thought to the writing which he has to do as a part of his professional work knows that it is no easy task to get his ideas on paper in satisfactory form. If he is ambitious in this as in other parts of his work, he will succeed in expressing himself adequately just in proportion as he is a clear and well-trained thinker and a keen observer of the ways in which other minds work. If, however, he feels he ought to approach the task of writing more intelligently and to that end tries to get assistance, he discovers that the kind of help he wants is hard to find. The problems of a technical report or magazine article, or of any of the longer works which engineers write, are many of them similar to those of general composition, of literary exposition, or of argumentation; but if the engineer turns for suggestions to treatises on these more definitely literary forms, he will find much that does not apply to his case, and he will fail to get guidance where he most needs it. Yet the special forms of engineering writings have not been studied in schools or given adequate treatment in textbooks. The reason for this lack is not far to seek. Teachers of English have generally felt that the writings of engineers were not worthy of special study as forms of composition; and, without investigating the case, they have assumed that the only preparation necessary for such writing was that given in the course in general composition. Engineers who have acquired the ability to write effectively, on the other hand, have seldom had time to give their less skilled associates instruction in composition. Nevertheless the fact remains that the

engineer makes use of a form of expression no less special than that of the lawyer, the novelist, or the poet; and he, no less than the members of other professions, needs special training in writing, over and above all that he may get in general composition.

Of late a few schools have introduced tentative courses in technical writing, and a number of textbooks are being put upon the market. So far the efforts have resulted mainly in publications of three sorts: (1) specimens of technical writings, which show the finished product but do not indicate to the bewildered writer how he may produce the best results; (2) dissertations on correct English together with notes for the guidance of authors in the submission of manuscript to publishers, which only add to the large number of valuable books already written on these subjects; (3) treatises on technical writing addressed, with "a certain condescension," to engineers, but in reality based on a study of literary exposition. No one of these would seem to get down to underlying principles or to deal with technical writing in a way which is general, yet definite and detailed enough to serve as a practical guide for the engineer. For these reasons a study of some of the fundamental problems of technical writing is undertaken here in the hope of offering suggestions that will be helpful to any engineer in his writing.

CONTENTS

THEORY AND PRACTICE OF TECHNICAL WRITING

CHAPTER I

INTRODUCTION

THE NATURE OF TECHNICAL WRITING

1. **The occasion for writing.** — The motives which lead the engineer to write are no different from those which impel others. As an undergraduate he produces "compositions" because he realizes his need of practice in writing, or, more often, because he is required to. When he has passed beyond the control of teachers, he, like others, writes because the circumstances of business or of friendship require it or because he sees the possibility of gaining money or fame. But the true motive in all cases lies deeper. We may not, like the ancient mariner, stop the wedding guest at the bridegroom's door to tell our tale, but whenever we have had experience that seizes upon our imagination we find inevitably in the experience itself the impulse to communicate it. If we feel that what we have experienced would be of value or of interest to others than

those our voice will reach, we hear the call of duty to write. At other times we may not feel the impulse ourselves, but others, recognizing the value of our experience, may seek to share in it. The rapid succession of experiences makes it impossible for any one to communicate more than a small part of what happens, and the difficulty of seeing clearly what is worth while for others and of recording the experience effectively may discourage many from writing anything; but the impulse comes to every one, nevertheless, in the experience.

2. Now whatever the special occasion for writing, unless the universal motive is behind it, the attempt at expression will be worth little. The poor results attained in school are very largely due to the fact that the student is required to write upon subjects in which he is not particularly interested and on which he knows he has nothing to say of real value to others. Out of school, whenever we write because we must to meet business or social requirements, the occasion is manifestly that of having something to communicate which will be of value to others; but we cannot write well unless we appreciate the real occasion. When we write for money or for fame, we do not succeed unless we find something to offer which others need or will gladly accept; and if the subject, after we have once chosen it, does not seem to us to have real worth enough to demand expression, we stand little chance of arousing the interest of others. The impulse to share experience springs, like hope, eternal in the human breast; and in that impulse, combined with the faith that the experience is worth the attention of others, lies the only real motive for writing. It is always tempting to the engineer to publish something for the purpose of advertising himself, but the profession is coming to recognize [1] that to be

[1] See *Engineering News*, April 16, 1908, "The Making of Literature for Engineers," Charles Whiting Baker.

justified in publishing, or even in writing in a less ambitious way, one must have something to communicate which will be helpful to others, either because it is new and valuable, or because it is presented in a more serviceable form than ever before.

3. **The rhetorical forms.** — A single experience even may give valuable material which will express itself in various rhetorical forms. If the engineer visits Panama, for example, he is sure to have a wide range of interesting subjects to write home about. He may undertake to tell his correspondent something of the country as he sees it: in that case the form of writing is called *description*. He may relate his experiences getting to Panama and traveling about in the Canal Zone: in that case the form of writing is called *narration*. He may explain the geological structure of the Isthmus or the method of carrying on the excavating: in either of these cases he would be writing *exposition*. He might tell a correspondent who intends to visit the Canal the best way to reach the Zone and to get the most out of a visit: in that case he would be writing *directions*. He might give in some detail his opinion of what another had written about the country or about the engineering problems: that would be *criticism*. In the last place he might attempt to convince his reader that the lock canal is after all the best form for Panama: in that case he would be writing *argument*. If the subject matter is created by the imagination instead of coming from an actual experience such as a visit to Panama, it does not affect the form. A description of Utopia is no different in form from a description of London; the exposition of a machine which is only designed is no different rhetorically from the exposition of one in actual operation. According to these six types, the so-called rhetorical forms of composition, therefore, all prose writings may be classed.

4. A word more needs to be said about each of these forms in order that the distinctive characteristics may be appreciated. The main purpose of the first two, description and narration, is to share with the reader some experience of the writer's, practically as it came to him from without; the purpose of the remaining four is, in each case, rather to give the reader the results of a process of thought. Of the two which share experience of things outer, description centers attention on objects which occupy space, real or imaginary; narration centers attention rather on events which make up a sequence in time. Of the other four forms, all of which undertake to lead the reader through a process of thought, each has a special object in view. Exposition aims to make the reader understand the facts; directions, to enable him to perform some action; criticism, to let him see the thing criticized as it appears in the judgment of the writer; argument, to lead him to adopt the judgment of the writer. In actual writings these forms so shade into one another and often are so interwoven that it is difficult to distinguish them; but to confuse them in writing is fatal. The untrained writer is continually describing when he should explain or criticize; he dwells on what he did when he should attempt to make the reader see what he saw; he explains his opinion when he should attempt to establish his judgment; or in some other way he fails to accomplish the purpose he intends because he does not realize that he is using the wrong form. Such rough definitions as those just given are not exact either logically or rhetorically; but if the distinctions which they make are carefully considered and remembered, they will help the engineer to avoid the practical confusion of rhetorical forms which is one of the commonest and most serious defects of the untrained writer.

5. **Literature and science.** — Whatever rhetorical form

the engineer uses, his writings may also be classed in one or the other of two different categories according to the subject matter. In writing about his visit to the Canal Zone, his main purpose may be to share with his friends at home the pleasure that his experience gave him, or it may be to impart to them information which he gained. Most writings which aim to communicate anything of more than brief temporary value, of whatever rhetorical form they may be, attempt to give in some proportion both pleasure and information; but, in this case again, unintentional confusion is fatal. The immature writer frequently undertakes to convey pleasurable experience and yet writes only " bare " facts. Even if the facts are worthy of note, they should always be kept secondary when the main purpose of the writer is to please. In other cases, the writer may aim to give instruction and yet allow digressions to creep in because they happen to interest him. These digressions may or may not be delightful to the reader, but they should never be allowed to obscure the information to be given. Because the purpose of giving pleasure and the purpose of giving information are so commonly combined in writing, we have no classifying terms which exactly mark the distinction; but in a loose general sense we may say that writing which aims mainly to delight is *literature* and that writing which aims mainly to instruct is *science*. This distinction the engineer of experience is seldom in danger of confusing in his technical writing, unless he is tempted into " decorating " his style, because he knows that in his professional work he is dealing wholly with science.

6. Now science, as we are using the term, is of three sorts: *abstract* science, which builds up general laws based on self-evident truths; *natural* science, which builds upon observation and experiment; and *applied* science, which employs both the general laws and the results of

observation and of experimentation in dealing with concrete phenomena. It is evident that the engineer's business is with applied science.

7. **Engineering writing.** — The writing which the engineer may have to do is varied in subject and in form. He may get the ideas he wishes to communicate directly from experience, he may get them indirectly through others, or he may, by recombining the elements of actual experience, create his subject matter in his imagination. The experience may come to him from without or it may be inner, that is to say, a process of thought. He may have occasion to use any one of the six rhetorical forms or any combination of those forms. In all the writing which he does in connection with his professional work it is evident, however, that his subject matter is applied science and that it is his main purpose to instruct. He does not describe or narrate for the purpose of producing a picture or a story. He may describe a simple implement, an electric light and power plant, or a metropolitan water and sewerage system; he may narrate the things accomplished in a single day's work, or the process of construction of a gigantic railroad bridge; but in all cases his main object is to make clear to his reader the facts. If he has to write directions, he seeks to enable his reader to do something; but the directions which an engineer has to write usually attempt and should attempt to explain as well as to direct. If he has to write argument or criticism, he is still generally dealing with facts of applied science which he must needs make his reader understand. In short, the writing which the engineer has to do is almost wholly exposition; more than that, it is only in as far as it is expositional that it offers any problems different from those which arise in general composition. If we center our attention, therefore, on exposition of the various types which the engineer has to use (descriptive,

narrative, and directions), we would seem to be on the track of all the special problems of engineering writing.

8. Qualities of style which the engineer should strive for. — The difficulties of this form of composition, which are serious, will be brought out definitely in the course of our study. The qualities to be striven for should be recognized at the start. They are four. First, the facts as expressed should be *accurate*. Second, the treatment of the subject should be *complete* for the purpose in hand. Third, the form of presentation should be *logical*. Fourth, the expression should be *economical* for the reader. Writing which lacks these four qualities is no more worthy an engineer than a piece of mechanical construction which is inaccurate, incomplete, improperly put together, or uneconomical.

Methods of Study

9. Outline of the subject as presented here. — In our study we shall consider, in Part I, the theory of technical exposition; then in Part II, the application of the principles in actual practice and the methods of obtaining the best results in writing. At the beginning of the theoretical part a method is explained by which we may analyze exposition and record the facts in a form of "synopsis" which shows definitely wherein the writing is or is not accurate, complete, logical, and economical. Next this form of synopsis is used for purposes of synthesis, that is to say, for building up the best structure. General principles are formulated and then applied, as a matter of theoretical study, to a few typical concrete subjects. In the second part of the book, suggestions are given as to the application of these principles in actual practice under different conditions. Then the form of the final writing is analyzed and a study is made of the rhetorical principles which should be observed. In conclusion,

suggestions are given as to methods of writing by which the engineer can reach the best results without serious waste of time. In the appendix brief examples of technical writing are given, not as models but as illustrations of better or worse ways of solving the problems. To these reference is made as different points come up for consideration in Part II.

10. The method of the book will perhaps be better understood from the following general plan: —

INTRODUCTION. Definitions.

- *A*. The nature of technical writing.
- *B*. Methods of study.
- *C*. Opportunities for training.

} CHAPTER I.

BODY. The theory and practice of technical writing.

- *A*. A study of the principles of logical structure.
  - I. Analysis of exposition by means of "synopses." CHAPTER II.
  - II. Synthesis. The theory of logical structure.
    1. Fundamental principles. CHAPTER III.
    2. Application of these principles.
       - *a*. To descriptive exposition. CHAPTER IV.
       - *b*. To narrative exposition. CHAPTER V.
       - *c*. To directions. CHAPTER VI.
       - *d*. To description, narration, and directions combined. CHAPTER VII.
- *B*. Practical application of these principles.
  - I. Logical structure in actual practice, illustrated by references to articles in the appendix.
    1. General suggestions. CHAPTER VIII.
    2. Addressing general readers. CHAPTER IX.
    3. Addressing specialists. CHAPTER X.
  - II. The form of the final writing.
    1. Indication of logical structure. CHAPTER XI.
    2. Other rhetorical principles to be observed in the final writing.

CONCLUSION. Methods of writing. CHAPTER XII.

APPENDIX. Illustrative examples of technical writing.

11. **How the subject may be studied by the engineer.** — To engineers, especially to those who seldom have occasion to write anything more pretentious than letters and short reports, the method adopted here may seem indirect, artificial, and unpractical. It would seem more natural to begin directly with actual writings and the formulation of practical suggestions. But the examples of technical writing which would have to be studied would be either too long for textbook treatment or too fragmentary (as models of rhetorical composition) to draw theoretical or practical conclusions from. More than that, technical exposition has received so little serious attention that the principles are seldom clearly understood or observed by the writers themselves. For these reasons a method of induction from actual writings would be very slow and indirect. On the other hand, the underlying principles are themselves simple and readily discovered; and after they have been formulated it is much easier to study actual practice and to draw conclusions. It is true that the treatment of the technical subjects used to illustrate the theoretical principles which this method necessitates is distinctly artificial. In order to lay a solid foundation of understanding, the elementary problems of technical exposition are taken up one by one and studied in artificial isolation to bring out the essential character of each. This makes the treatment of the subject matter different from what would be given in practice; but the method is similar to that followed in the chemical laboratory where, at first, chemical elements are isolated and studied in an artificial way. The object of all this study is to bring out separately and distinctly all the steps of logical processes which the trained mind passes through rapidly and almost unconsciously. *The engineer who has not the time for this minute study or who feels he does not need this logical drill may*

easily shorten the process. The outlines at the beginnings of the chapters and the various headings within the chapters make it possible for one to go through the book and glean what is desired only. The whole of Part I may be glanced over and study given only to Part II, the practical suggestions. Reference is made in Part II, wherever it might be helpful, to sections in the theoretical study; and for the more mature writer it might be much more interesting and suggestive to consider theoretical principles after practical suggestions.

12. **How the subject should be studied by the undergraduate.** — For the undergraduate, the earlier chapters are of special value. It is with textbook treatments of subjects, such as are considered in these chapters, that he is brought in contact in all his work, and in mastering the facts and the processes of thought of those books he needs much help. He needs also, in order to learn to write effectively, to study cases where the principles of technical exposition are brought out unmistakably and fully, and where they are not obscured for him by the difficulties of the subject matter. Though the method adopted here will not give him at once suggestions which, without work on his part, will help him in the writing he has to do, it will give him what he needs most of all, a severe logical setting-up drill.

13. **How the book may be used by the teacher.** — The teacher using this book will probably do well to take up a single chapter at a time, following the order as presented. It is possible to include this work as an important part of a more general subject in composition for engineers or to make it a separate subject to be taken in the sophomore or junior year. For the more complete study the following method, based on ten years' experience with the subject, is offered as a suggestion: —

1. The analysis (according to the method explained in Chapter II) of several short articles from the students' text-

books or from current engineering magazines, including if possible two or three treatments of the same subject.

2. The writing of five papers similar to those discussed in Chapters IV, V, VI, VII, and IX, the subjects being assigned from work the students are doing or have done in other classes. In all cases it is better to have the papers written and analyzed *before* the appropriate part of "Technical Writing" is studied.
3. The analysis of a single book for the purpose of bringing out its structure; and of paragraphs and sentences from various technical writings. The study of the rhetorical principles discussed in Chapter XI.
4. The discussion of special problems which arise in practice and of methods of writing.

The analysis of technical articles gives training in writing synopses, which is valuable drill, and the opportunity for preliminary investigation and discussion of fundamental problems of technical exposition. It should be remembered that the writings of even an eminent authority are not necessarily model expositions.

Each of the five papers should be written several times, for little can be accomplished by off-hand writing, particularly at the start. It has been found most satisfactory to have the class write a synopsis, then a second synopsis, then a finished draft in the final form. If the results are unsatisfactory, a third synopsis or a second final writing may be of sufficient value to risk exhausting the not over-strong patience of the student. Or if it is desired to cut down the amount of work, only the synopses of the first papers need be written and one synopsis and a final writing of the later papers. Each subject should be carefully criticized in the light of the appropriate chapter, not only in class but in conference with the individual writer, before another writing is attempted. A few subjects studied thoroughly are more helpful than many subjects gone over hastily. The idea is to give thorough training, which not only enables the student to learn something about technical writing but necessitates his having a real understanding of the subject matter.

14. This method means that the teacher has to read technical textbooks and consult authorities on the subject matter to be written about. This entails much work,

but the amount may be cut down in two ways. In the first place, not more than one or two new subjects need to be introduced in a year, so that the teacher may get a thorough understanding of the subject matter without overburdening himself. In the second place, if the students are allowed to choose their own subjects at any time, they may be required to bring in with the paper a standard textbook dealing with the subject, in which they may be asked to verify the facts whenever it would be advantageous. In these ways the teacher may be freed to center his attention on the form of presentation, without permitting the idea to grow up in his mind or in the minds of his students that anything written for a teacher of English may be less accurate than if written for others. No effort has been made here to get up labor-saving devices; the materials and subjects for use in class should not be taken from a textbook on English composition, but from the engineering publications which the students are actually reading.

Opportunities for Training Offered by This Method of Study

15. In the opinion of many, all that a teacher of English has any occasion to do in helping an engineer in his writing is to go over the final draft to correct the spelling, drop in more commas, tinker up weak sentences, and remove words which offend against good use. Such work is important, and is all that needs to be done provided the writing is really ready for such finishing touches. Usually, however, there are shortcomings of a more fundamental character, and the first and the important thing is to remove these. The main work to be done in any course in composition is to learn to give to writing the essential qualities of the particular rhetorical form which is being

used. Thought and verbal expression are practically inseparable, consequently the main purpose of a course in technical writing should be to train one in thinking and in expressing oneself accurately, completely, logically, and economically.

16. **Accuracy of expression.** — The undergraduate seldom has learned fully to appreciate what accuracy means, either in observing, in thinking, or in recording. Each of his teachers is striving to develop that appreciation, but because of the hurried way in which much of the work is gone over, because of the size of the classes and the consequent small amount of time given the individual member, and because the teacher of technical subjects must usually be satisfied with results and can seldom adequately criticize in detail the mental processes by which those results are reached, the student is in danger in much of his work in all departments of continuing or even of developing slipshod methods which will seriously stand in the way of his advance. In an English class it is possible to give valuable training through studying a few elementary subjects with sufficient attention to develop a high degree of accuracy in observation and in thinking as well as in expression.

17. **Completeness of treatment.** — It is often said that the result of school and college training in English is to develop the habit of using too many words. The "practical" man has repeated, sometimes *ad nauseam*, his injunction, "Boil down!" And the use of words not required by the thought is always a most serious defect. The teacher should strive at all stages against even the appearance of padding. But it is useless to attempt to "boil down" till there is something worth boiling. What in the immature writer often seems like an overabundance of words is generally a lack of real and definite ideas. He is ready to skim over an important subject, touching a

point here and there — not the essentials, but those details which happen to enter his mind at the moment — and feel that he is giving a worthy treatment. There is special danger of such crude superficiality when an engineering student writes technical papers for an English teacher who, he expects, will be unable to give serious attention to the subject matter. The student in the English class should be allowed to write only on those subjects about which he can gain real knowledge, and should be required to get all the essential facts and to express them fully, in order that he may learn to appreciate what adequate treatment is. The technical subjects considered in the theoretical part of this book are all handled with this in view, not with the object of producing practical treatments. The value of such training is so great that little harm will result if, at the start, "completeness" is overemphasized.

18. Logicalness of form. — The universities of the Middle Ages devoted a great part of their time to the study of formal logic and to the application of logical principles. Nowadays we feel that the subjects discussed at such length were of little real value, but no one has yet devised a better form of mental discipline. When this study was largely abandoned, its place was taken by Latin; and undoubtedly that subject, when taught as it has been in the best English schools and universities, is of inestimable value as a trainer of exact expression and consequently of exact thought. Now students, especially engineers, get little if any of such drill, and the natural results show in the writings of technical graduates. If a teacher attempts to insist on accurate thought and accurate expression on the part of his students, he finds that he is struggling against the general trend of present-day education. Nevertheless, well-developed logical power is as much needed now as it ever was, and in a course in

technical writing the engineering school has one of the best opportunities to give drill which is equal to that of the old logical or linguistic courses. The work may be made just as thorough, as far as the time limit will permit, and just as high ideals of logical accuracy may be set up; and in addition the subject matter is of direct value and of interest to the student.

19. Many believe that the technical engineering classes themselves offer enough opportunity for mental discipline; but most of that work is defective as a trainer of thought in two ways which it is the privilege of the English course to amend. In the first place, a large part of the thinking which the student does in his scientific work is carried on with the objects of his thought at hand; but in designing, inventing, planning, and organizing, that is to say, in the most important part of his professional work, he has to carry on the more difficult process of reasoning where the objects are present only as ideas. A student who has used a transit satisfactorily for two years or more in his surveying often is unable to think accurately about the working of even the essential parts if he has not the instrument before him. In the English class he is trained in explaining objects and processes with nothing to depend upon but his own ideas. In the second place, much of the thinking which his scientific work leads him to he carries on by means of visual images or of symbols for ideas instead of by means of words. But words and thoughts are so nearly inseparable that there is always danger that the exact thought is not there when it is not put into words; and in order for any one to share ideas, especially with those lacking his special training (with whom and for whom the engineer must largely work), he must learn to express himself effectively in words. Often students find it a burden to write synopses and to "quibble" as it may seem over

minute details of elementary subjects, but such work, even if it is dull, will train one to move accurately, and in time rapidly, to logical results, and will lay a valuable foundation for all college and graduate work.

20. **Economy of presentation.** — From the first the engineer should be trained to express himself concisely; but after he has learned what it means to write accurately, completely, and logically (and not before) he will find it helpful and necessary to apply the true boiling down process. He should be taught, on the one hand, to omit everything which the special occasion on which he is writing does not call for; on the other hand, to express what he does undertake to explain in every case so that his readers will get his ideas without unnecessary effort. The technical writer needs careful training in making himself clear, and particularly in making himself clear to readers of different grades of knowledge and of interest.

The Aim of This Book

21. Both practical engineers and undergraduates may feel that the road which this book lays out before them is unnecessarily long. Although they may realize that it is difficult or impossible for them to write effectively, and although they may desire to get help, they may wish the help at once and with little expenditure of effort on their part. This book does not attempt to give any one skill, it simply suggests definitely where the difficulties probably lie and what may be done to overcome them. Mastery of expression comes to most slowly and only as the result of much earnest endeavor and hard labor. Let no one flatter himself that technical writing is easier than any other form, if the aim is to gain real mastery. Painstaking self-drill at an early stage may save the engineer years of blundering effort.

PART I

A STUDY OF THE PRINCIPLES OF LOGICAL STRUCTURE

CHAPTER II

ANALYSIS BY MEANS OF SYNOPSES

Analysis of "The Transit" (Article I, Appendix).
General outline, § **23**.
Details of the first paragraph, § **24**.
A complete "synopsis," § **25**.
What is meant by a synopsis.
Definition, § **26**.
System of indicating the relations of the ideas, § **27**.
Rules to be observed, § **28**.
The value of writing synopses for the purpose of analysis, §§ **29, 30**.

22. For purposes of analysis we shall use Article I of the Appendix on "The Transit," which we shall study for the present simply to show a way in which the facts given may be expressed so as to bring out clearly the logical structure.

Analysis of "The Transit"

23. **General outline.** — A brief examination of this article shows that the first paragraph gives a definition of the transit, the second explains the general structure and the general method of using the instrument, and the remaining paragraphs present the details of construction. Evidently it is the purpose of the writer to explain the structure of the instrument, consequently with paragraph 2 begins what we may call the *Body* of the article. The first paragraph, which does not explain any part of the structure directly, but rather serves to lead up to the subject by defining the instrument, we may call the *Introduction*. The Body, we have seen, is divided into two

main parts. So much of the structure of the article may be expressed in the form of the following brief outline: —

THE TRANSIT

INTRODUCTION. Definition of the transit.
BODY. Construction of the transit.
  A. The general structure and general method of using.
  B. The details of construction.

24. **Details of the first paragraph.** — If we examine the first paragraph in detail, we find that it defines the transit by telling the different purposes for which it is used. There is, first, the general and characteristic use; and secondly, those uses made possible by the presence of "special attachments." With the attachments, the transit is used, first, "for measuring," and, secondly, "for leveling." The possibilities of measuring with the attachments, as given here, are two: for measuring "vertical angles" and for measuring "distance." These different divisions and subdivisions we may indicate in the same way in which we expressed the relations of the main parts of the article in the brief outline in section 23, using different indentations and different "markers" (27) to indicate the different grades of division. In this way we may express the substance of the first paragraph in the following form: —

INTRODUCTION. (Definition.) The transit is the instrument most used by surveyors and engineers
  A. for measuring horizontal angles,
  B. with certain attachments,
    I. for measuring
      1. vertical angles,
      2. distance,
    II. for leveling.

25. **A complete "synopsis."** — If we express the facts of the whole article in this way, we bring out clearly the structure in a form we may call a "synopsis."

THE TRANSIT

INTRODUCTION. (Definition.) The transit is the instrument most used by surveyors and engineers

- *A*. for measuring horizontal angles,
- *B*. with certain attachments,
  - I. for measuring
    - 1. vertical angles,
    - 2. distance,
  - II. for leveling.

BODY. (Construction of transit.)

- *A*. (General structure and general method of using.)
  - I. (General structure.) The transit consists of
    - 1. a telescope, with
    - 2. means of attachment to
    - 3. a pointer, which has
    - 4. means of movement around
    - 5. a graduated circle.
    - 6. Attachments [1] for controlling motion of telescope and pointer,
    - 7. attachments for enabling graduated circle to be made horizontal.
    - 8. Means of clamping pointer to graduated circle so that they may be revolved together.
  - II. (General method of using for measuring horizontal angles.)
    - 1. Pointer is clamped to graduated circle,
    - 2. the two revolved till telescope is pointed to a given object,
    - 3. graduated circle is clamped so it will not revolve,
    - 4. pointer is then unclamped from circle,
    - 5. pointer and telescope are turned together till telescope points to a second object.
    - 6. The number of degrees of the circle over which the pointer has passed will be the angle subtended, at the point where the transit is placed, by the two objects seen through the telescope.

[1] As far as possible capital letters are used to indicate the beginnings of sentences in the article.

B. (Details of construction.)

I. Pointer is zero mark of a vernier. Usually two double verniers 180° apart.
II. Telescope, *T*, Fig. 46.
III. Horizontal axis, *A*, by means of which telescope may be revolved in vertical plane.
IV. Bearings on which axis rests at top of
V. standards, *X*, rigidly attached to
VI. circular plate that carries the
VII. verniers, *V*.
VIII. Two level tubes on this plate to show, when adjusted parallel to the plate, whether plate is level.
IX. Conical axis, on which plate revolves, made by maker perpendicular to plate so when plate is level axis is vertical.
X. Conical sockets, in which above-mentioned conical axis fits, which socket is, in turn, inside
XI. conical axis of
XII. plate that carries
XIII. graduated circle.
XIV. Top plate,
XV. bottom plate, connected by
XVI. socket, in which axis of graduated circle plate revolves.
XVII. Leveling screws, *L*, to level upper plate.
XVIII. Screws for attaching lower plate to the
XIX. tripod.
XX. Clamp *C*, to fasten vernier plate (called sometimes the *alidade*) to graduated circle plate, called the *limb*.
XXI. Tangent screw, *S*, by means of which vernier plate, after it is clamped to limb, may be moved a slight amount to set vernier or point telescope more precisely.
XXII. Collar, *K*, surrounding spindle of limb,
XXIII. clamp screw, *C′*, to fasten collar to spindle.
XXIV. Lug, *M*, attached to collar, held so as to prevent revolution of limb, when collar is clamped to axis, by
XXV. spring in
XXVI. barrel, *P*, and

XXVII. opposing screw, S', fastened to upper leveling plate, which is a tangent screw permitting a slight movement of limb.

What is Meant by a Synopsis

26. Definition. — A "synopsis" of a piece of technical writing is, it may be seen, a restatement of the substance of the piece so arranged that each "fact" (28, Rule 3) is brought out separately, and the relations between these facts are indicated by a system of indentation and of lettering and numbering, similar to that commonly used in formal briefs.

27. The system of indicating the relations of the ideas. — What method of lettering and numbering is used is a matter of little importance, but it obviously saves confusion to stick to a single system. Throughout this book such main parts as the Introduction and the Body will be marked with the appropriate word; other divisions will be indicated as follows: —

A. (Capital letters for main divisions of Introduction, Body, etc.)
- I. (Roman numerals for subdivisions under all main divisions.)
  - 1. (Arabic numerals for all sub-subdivisions.)
    - *a.* (Small letters for divisions of sub-subdivisions.)

If more minute division is required, as not infrequently happens, the small letters of the latter part of the alphabet may be used, then Greek letters.

28. Rules to be observed. — It will be noted that the synopsis given above (25) observes certain rules, and a careful consideration of what the synopsis attempts to do will show that these rules should be observed in making out a synopsis of any piece of technical writing. They may be stated as follows: —

1. *Every "fact"* in the original writing should be included in the synopsis.

2. The facts should be given in the *exact order* in which they are presented in the original.
3. *Each fact should be given a separate division.* Just how much constitutes a "fact" as the term is used here depends on the subject. It will be seen by referring to the synopsis (**25**) that in the Introduction the "facts" are the different processes for which the instrument is used, that in Body A. II. they are the steps in a single process, that in Body B. they are the separate structural parts of the instrument.
4. The *relations* between the facts, indicated or implied in the original, should be fully expressed according to a system such as that explained in section **27**. In certain cases it is helpful to bring out relations a little more fully by the use of words. Such verbal indications of relationship are given in the synopsis of "The Transit" (**25**) in parentheses.
5. *As few words as possible should be used.* If the original is carefully written, but few words may be omitted in the synopsis, and in expressing the relations of the facts words sometimes have to be used in the synopsis which do not appear in the original. For example, in the synopsis, Body A. I. 8 is "Means of clamping pointer to graduated circle," etc., and Body A. II. 1 is "Pointer is clamped to graduated circle"; while the original merely says, "The pointer may be clamped to the graduated circle," etc. and, "If this is done," etc. The synopsis should, however, express the facts in as few words as possible and the relations as fully as possible by the system of lettering and numbering.
6. The wording should be changed, in certain cases, so that *coördinate parts* of single divisions may be *expressed in coördinate grammatical forms.* For example, in the following bit of the synopsis the changes made for this purpose are indicated by italic letters: —

BODY. *A*. I. (General structure.) The transit consists of

1. a telescope, with
2. *means of attachment* to
3. a pointer, which has
4. *means of movement* around
5. a graduated circle.

The original says, "a telescope *attached to* a pointer which *may be moved* around a graduated circle." The

reason for such changes is evident. It is a simple matter when we are giving a list of objects to use all nouns, and when we are giving separate steps in a process to use all verbs; and when it is our main purpose to bring out exact relations it is certainly unfortunate to "add together" nouns, finite parts of verbs, and participles, promiscuously.

The Value of Writing Synopses for the Purpose of Analysis

29. The value of writing such a synopsis for the purpose of criticizing a piece of exposition is apparent. In the ordinary form of writing, facts may be so combined that inaccuracies easily escape the reader; but when each fact is given a division by itself, accuracy or inaccuracy is at once set out distinctly for any one who knows the facts. The completeness is easily tested in the synopsis, for it is possible to check off at a glance the scope of the subject, and to discover if each division is treated with a completeness proportionate to its importance; whereas in the original writing it would be necessary to read the whole over carefully and perhaps to tabulate the facts in the head or on paper. Above all, the synopsis lays bare and magnifies the logical structure. In reading the original writing, if the structure is logical, we get all the consequent advantages, it may be, without having our attention directed to the structure; if it is illogical, we may be seriously distressed without being able to discover the cause. The synopsis shows the relations, not only of each fact to the one preceding and to the one following, but also of each to all the others. We may pass directly from one fact to any other anywhere in the writing and know what the interrelations are without reading what comes between, by simply observing

the place of each in the scheme of lettering and numbering. In the last place, unnecessary words are disclosed by the very act of writing the synopsis and unnecessary ideas may be detected readily by checking off the members of each division. Criticizing in this way is a slow process at the start, but when a synopsis is once written the article may be criticized rapidly and very thoroughly.

30. The engineer seldom cares or needs to make such a thorough analysis for purposes of criticism. As a means of learning something of the secrets of effective writing, however, he would find it most serviceable. There is no better method of self-training in technical writing than to discover and check off the good and the bad qualities in exposition by means of synopses. For one who is going to make a systematic study of the subject as presented in this book, it is important to write carefully two or three synopses of different articles, in order to gain familiarity with the form and with the rules which have been formulated. The most important use of the synopsis, however, is for purposes of synthesis, which is considered in the following chapters.

CHAPTER III

FUNDAMENTAL PRINCIPLES

General principles of accuracy, §§ **32**, **33**, completeness, § **34**, logicalness, § **35**, and economy of presentation, §§ **36–38**.
Principles of logical structure, § **39**.
Rules for the form of synopsis, §§ **40–47**.
Principles of order, §§ **48–54**.
Principles of division, §§ **55–66**.

31. Whatever an engineer may attempt to write in connection with his professional work, his whole problem is to give to his expression the four qualities which we have already considered (8, 16–20): accuracy, completeness, logicalness, and economy of presentation. The working out of this problem is somewhat different according to the rhetorical form which it is necessary to use (Chapters IV–VII), and above all it is different according to the kind of reader addressed (Chapters IX–X). But aside from these special applications, there are certain general principles which it is important to understand at the start because they represent the foundation on which all special applications must be built. In this chapter we shall consider the four cardinal qualities and thereby determine what we should lay down as fundamental principles.

General Principles of Accuracy, Completeness, Logicalness, and Economy of Presentation

32. **Accuracy.** — There should be no need of emphasizing the importance of accuracy to the engineer. In gathering his data, in making his records, and in thinking

out his conclusions, he must strive for this quality first of all. But that is not enough in writing: if a reasonably intelligent and attentive reader of the sort he is addressing gets a wrong idea, the fact that the writer can himself find the right idea in what he has written makes little difference. He should at all times make it his business to build up an accurate understanding in the mind of his readers.

33. In certain cases in technical writing, however, the primacy of accuracy is sometimes ignored or even denied by professional writers. In dealing with technical subjects for "the general reader" some think that at times the main object is to interest. The result is the so-called "popular science." But to think that science in order to be popularized must or may be inaccurate is a serious confusion of ideas. The main purpose of scientific writing is always to instruct. If the purpose in a given case is to turn toward a certain subject those who are not naturally attracted to it, the special purpose, it is true, is to interest; but it is to interest in science and for the purpose of instructing in science, and that which is admittedly inaccurate is no longer science. Many writers on scientific subjects in popular periodicals make it their only purpose to interest, and consequently do not hesitate to sacrifice facts for effect or to write glibly on subjects of which they themselves know little. Such work is beneath the attention of the scientist. In writing for the uninformed, additional care if possible should be taken, for they cannot, like the specialist, correct untruths from their own knowledge. It is a difficult and an important task to write on scientific and technical subjects in the language of the layman and in such a style as will arouse the interest of the general reader. Legitimate means of so presenting subjects without sacrificing accuracy will be considered in Chapter IX; elsewhere in this book that

special problem will not be considered. On the other hand, *the necessity for accuracy will not be further emphasized, because it will be taken for granted that the first principle in all technical writing is to express ideas so that they will be understood by the readers accurately.*

34. **Completeness.** — Completeness is a relative term and has to be given definite meaning for each subject treated. The history of the world may be written in a single sentence, in a paragraph, a chapter, a single volume, a set of volumes, or in a vast library of books. No one of these treatments would be absolutely complete, but each might serve a legitimate purpose, and if it accomplished its special object adequately, it would be "complete." The writer has always to consider, first, the extent of his own knowledge of the subject, and secondly, the knowledge, the needs, and the interests of those whom he is addressing. Often he has to consider time and space limitations: he has the opportunity of speaking ten minutes or an hour; he will be allowed to fill a single column or he can find sale for a single portable volume. One of the serious difficulties in writing is that of determining just how much the purpose in hand calls for. Some of the different phases of that question are considered in sections 84–86, 189–191, and 224. The principle which we can lay down at present is that when the writer has once determined how broad and how minute a treatment of his subject he is permitted to write, he has defined for himself the scope and should cover that completely, and should cover each division of his subject with a completeness in accordance with its relative importance.

35. **Logicalness.** — We might conceive that a writer had collected all his data, had expressed them accurately and completely, but still had them all as separate facts, on different pieces of paper, it might be. We see at once

that no "composition" would as yet be effected. The facts must be built together into a single structure. In order that they may be available for rational beings, they must be constructed according to habits which govern all normal minds. There are certain things which the human mind cannot do and other things which it can do only with great difficulty. For example, it cannot believe that a thing both exists and does not exist at the same time; and it can only with great difficulty go through a familiar chain of ideas in a new way, as we find if we attempt to say the alphabet backwards. When we speak of giving ideas logical structure we mean so putting them together that the reader will get them and their interrelations without going against the habits of his mind as a thinking machine and without having his attention distracted through wondering why the ideas were so put together. Building up logical structures is the main part of the problem of expression with which we are dealing, and we shall spend the remainder of this chapter, after the next three sections, in formulating the general principles of structure.

36. **Economy of presentation.** —A subject is presented economically (1) when it is free from all extraneous matter and (2) when it is so clear that it puts no unnecessary burdens on the reader. That economy depends on these two factors should not be overlooked. Some writers consider that they have done their whole duty if they have expressed themselves briefly; others, if they have made their point clear. The real problem is to exercise these two virtues, and that is often a question of striking a balance.

37. *Extraneous matter* may consist of words or of ideas. Unnecessary words should always be guarded against. Idiomatic English tends strongly to the introduction of prepositions and adverbs, sometimes of other parts of

speech, which are not strictly needed. Lack of care in sentence construction is continually leading to clumsy circumlocutions; looseness of thought and vagueness of language betray writers into vain repetitions. Words which do not perform full service should be stricken out, for at best they are but supernumeraries which stand in the way of their betters. This is a matter of general composition, but will be discussed further in Chapter XI (295–298). Extraneous ideas are of various sorts. Steps which strict rules of logic require are sometimes so inevitable that the reader cannot help taking them though they are not expressed. Ideas which would be inserted on the principle of completeness, the reader may already have so clearly in mind that he does not need to have them called to his attention. When it is economical to omit such ideas will be considered in Chapter IX (189–191) and in Chapter X (224). Aside from these two classes of ideas, extraneous matter generally takes the form of digressions. No single fact points in one direction alone. Side excursions are often tempting, but if we were to follow out all leads of even a single fact we should never get ahead. To present a subject intelligibly we must follow one general line of development. There are times when digressions are permissible and the ways in which they may be introduced without serious confusion will be considered in Chapter IX (191) and in Chapter XI (274). Till then we shall adopt it as a principle to give all technical subjects logically complete but straightforward treatment.

38. *Clearness* depends on various factors. Extraneous matter of any sort tends to make it harder for the reader to get the meaning, either because too many words in proportion to the ideas destroy interest and lull the attention to sleep, or because too many ideas distract and confuse the reader. On the other hand, if the state-

ments are too bare, even if they are logically complete, they may compel the reader to go over the subject several times in order to get the full meaning or application. If further explanation or illustration would enable the reader to get the whole idea on the first reading, the addition may be entirely justified on the ground of economy. In avoiding both the evil of verbosity or digressiveness and the evil of bareness of treatment, the writer should always remember that it is economy of the time and effort of the reader not of the writer that is to be sought. If the writer is the only one who can deal with the subject, and others need the information he can give, he will be read, no matter how poorly he expresses himself. Few, however, have such opportunities. Most write on subjects on which others have written and will write again, or on subjects which others will not read at all if presented in a way which seems unnecessarily difficult. When an engineer writes even a simple report on work he has done, the facts are needed by some one, and he perhaps alone can give them; yet if he writes his report so that an unnecessary amount of time is required to get at the facts, that is a defect and a good reason, if it is not remedied, for getting another man who can do that part of the work better. It is often difficult to decide how much the writer should do for the reader and how much he should leave for the reader to work out for himself, but that can be determined only in the specific cases. In explaining whatever it is the business of the writer to make clear, however, if a slight saving may be effected for the reader, the writer should make it, even though it cost him much time and labor, for there is but one writing while there may be very many readings. The burden, as far as possible, should be assumed by the writer.

Principles of Logical Structure

39. The building up of a logical structure is not all there is in technical writing, but it is the most important part and the one essential at the start. Within this structure may be determined all the preliminary questions of accuracy, completeness, and economy; within it, too, may be settled any special problems which arise from the character of the readers addressed. Problems which are not matters of logical structure may all be left till that structure has been worked out and the shaping of the final writing (Chapter XI) is begun. We have already seen (29) that an excellent way of discovering and of testing the structure of exposition already written is to write a synopsis; in a similar way synopses may be used as a means of building up logical structures. When it is an advantage to go to the trouble of writing a synopsis and exactly what the advantage is, will be considered in Chapter VIII (154) and in Chapter XII (324). In the following four chapters we shall use the synopsis as a means of building up logical structures; and in the remainder of this chapter we shall concern ourselves entirely with the general principles according to which synopses should be shaped.

RULES FOR THE FORM OF SYNOPSES

40. If a synopsis is to have a structure which is strictly logical, it should observe certain rules of form. These include the six already given (28) as applying to synopses written for purposes of analysis and two other important rules. All will be stated here, for the first six need to be worded somewhat differently to fit synopses written for purposes of synthesis.

1. *Every "fact"* (**28**, Rule 3) that logic demands should be presented in the final writing should be given in the synop-

sis, and no fact should be included which is not to appear in the final writing.

2. The facts should be given in the *exact order* in which they are to be expressed in the final writing.
3. *Each fact should be given a separate division.*
4. The *relations* between the facts should be expressed by a system of indentation and of lettering and numbering (**27**).
5. As *few words* as possible should be used.
6. The *wording* should be such that the coördinate parts of any single division, great or small, should all have coördinate grammatical forms.
7. All the coördinate parts of any single division, great or small, should be *coördinate in fact* as well as in form.
8. Each division, great and small, should be *equal to the sum of all its parts.*

41. The two rules (7 and 8) which have been added to those previously given are also implied in the nature of the synopsis, but do not need to be considered in the case of the analytical synopsis, for such a synopsis must follow the article which it is analyzing, and that may not be logically constructed itself. Each of these rules is, however, very important for purposes of synthesis and needs further explanation and illustration.

42. All the coördinate parts of any division should be *coördinate in fact.* We have already considered (**28**, Rule 6) the necessity of having coördinate parts worded alike; but it is a matter of more than wording. Only fractions of common denominator can be added. If we attempt to combine promiscuously in a single list objects and acts, wholes and parts of coördinate wholes, we are doing something which is essentially irrational. The moment we jump about in explanation from object to act and from act to object, we are introducing confusion for our reader and are in great danger of becoming unclear in our own thinking. For example, in the synopsis of "The Transit" (**25**), in Body A. I. (which is describing the general structure), an explanation of the process of

making the circle level would be a digression at this point which would tend to blur the impression of the structure of the transit on the reader's mind. Similarly, in Body A. II. (which is explaining the general method of using the instrument), a detailed description of the "pointer" would tend to confuse the reader as to the process. And either addition might lead the writer to overlook important parts of the explanation. Again, if we put together in one and the same list terms which express single parts and terms which express groups of such parts, we are introducing confusion. In a list with the "alidade," for example, might well go the "lower motion," the "leveling head," and the "tripod"; but not the "lower tangent screw" or the "lug," for the alidade includes a group of parts each of which is of the same grade as the tangent screws and such parts. Many articles which are confusing on first reading will be found on analysis to produce that effect because they group together ideas which are not coördinate.

43. *Each division should be equal to the sum of all its parts,* no more and no less. Of the synopsis of "The Transit" (25), the following equations, for example, should be true: —

Introduction B. (uses of transit with attachments) = I + II.

Introduction B. I. (things which transit-with-attachments measures) = 1 + 2.

Body A. I. (general structure) = 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8.

Body A. II. (general method of using) = 1 + 2 + 3 + 4 + 5 + 6.

Body B. (details of construction) = I + II + III, *etc., to* XXVII.

This rule expresses a simple principle which needs little explanation or justification, yet an astonishing number of minor defects and many of the most serious faults in

technical writing will be found on analysis to be due to failure to observe this logical necessity.

44. A few concrete cases will make the application of this rule clearer. If in explaining the "details of construction" of the transit (Body B), the writer includes attachments for performing operations not indicated in the Introduction, then the subdivisions of Introduction B (the transit-with-attachments) are not complete. Introduction B = I + II is, then, not a true equation, for the details of construction show that *of the transit which the writer has in mind,* the true equation is B = I + II + *something else.* It is always possible to indicate that an equation is incomplete, that is, only suggestive, by the use of some such expression as "with attachments for *such operations as.*" Unless such an expression is used, it is illogical and confusing to the reader when the sum of the parts is less than the whole. Similarly it is illogical if the details of construction omit parts necessary for performing any of the operations mentioned in the definition. If the transit which the writer has in mind can perform all the operations, the necessary parts should be explained; if he is considering a transit without those parts, or if he desires for good reason to present an idea of the transit without them, he is entirely justified in not mentioning those parts in the details of construction, but he should, then, change the statement in the Introduction. The original equation B = I + II would not be a true equation, for the details would show that the B intended in this particular case = I + II minus something.

45. If a term is omitted at the point where it logically belongs, inserting it at another place, where it does not belong, does not remove the inaccuracy. If, for example, in explaining the alidade the verniers are not mentioned, the reader is given a false or incomplete idea of the alidade. But if the writer inserts this missing fact in his explana-

tion of the limb, saying that position on the limb is read by means of the verniers, he does not correct his false statement about the alidade; instead, he makes his explanation of the limb illogical, because the verniers are not a part of the limb. Much confusion, arising from "false equations," is introduced by writers who are not particular where they place their facts. After-thoughts, instead of removing the defects caused by the omission of facts, in reality double them.

46. If an idea is repeated, that is to say, if a fact is expressed twice in exactly the same sense, the truth of the equation is destroyed. If, for example, the "general structure" (Body A. I.) were expressed as it is except for the addition of three words, as follows, "a pointer which may be moved around *or clamped to* a graduated circle," the equation, which would then be A. I. $= 1 + 2 + 3 + 4 + 4' + 5 + 6 + 7 + 8$, would be untrue, because $4'$ and 8 would be the same factor: the means of clamping the pointer to the graduated circle. An item may in many cases be repeated without destroying the truth of the equation, for the same thing may serve two purposes, so that what seems like one item is really two. For example, the screw, 76, Fig. 1, § 77, is the tangent screw used for exact sighting of the telescope in the vertical plane, and it is also in some instruments the "gradienter" sometimes used in grading. The bringing in of a single fact in two or more relations, each of which is required by the subject, is frequently necessary and should never be avoided on the ground that it seems like repetition; but any repetition of a single fact in a single relation destroys, in so far, the logical structure.

47. Often a writer in some such ways as these gives one idea of his subject or of a part of it in one place, and later gives a contradictory idea; or, what is worse, he gives one idea in one place and later carries on his expla-

nation with a contradictory idea in mind, which he has not even stated. Since completeness, as we have already seen (8, 34), is always a relative term, what is meant by the " sum of all the parts " must be decided for each subject and for each treatment of a subject, and this is at times a difficult thing for the writer to do; but it must be determined rationally in relation to the object which the writing is to serve, it must be carried out consistently throughout the paper, and it must be so expressed that the reader will get the sense of completeness. If the sum of the parts is less than the whole or more than the whole, if a fact gets in at the wrong place or gets in twice, the equations are false, as a synopsis would show, and however difficult it may be to discover that fact in the final writing, inconsistencies of this sort seriously lessen the efficiency of the presentation.

PRINCIPLES OF ORDER

48. **Importance of order.** — In addition to the questions of coördination and of subordination which we have just been considering, there are questions of order of presentation. If there are, for example, four main divisions, they may be strictly coördinate, and the sum of the four may exactly equal the whole subject; still the writer must decide which division should come first and in what order the others should follow. Similarly the order of lesser divisions must be decided upon. Every one realizes that the massing of the facts is important in exposition, but the full significance of the order of presentation may not have been considered.

49. When we are thinking (instead of writing) about a complicated instrument with which we are perfectly familiar, it makes little difference what part we direct our attention to first, for we understand the instrument as a whole and it is in a vague sense present to our imagina-

tion as a whole, so that we can give intelligent attention to any point we wish. From the point at which we start, whatever that may be, we can skip about in our thought as we will; association of ideas will carry us along by some sort of connections from one part to another. Unless our mind is unusually logical it will not hold strictly to any single plan throughout the whole process of thought. If we omit an important point, we can easily go back and pick it up; we can jump about and double on our track with perfect freedom, for thought is so rapid there is little waste of time or energy in such an indirect course. More than that, at every step in the process the whole instrument is nearly enough present to our attention so that in addition to the single line of thought which we are trying to carry on there may be many side plays at every moment; indeed at each step the mind is almost inevitably playing all about the special point on which attention is purposely centered.

50. Now when a writer is attempting to present to others an explanation of an instrument which he can think out in this way, he is compelled to reduce all this multiplicity and disorder to a single line of thought and hold the reader to that line. This is the fundamental limitation of spoken or written language as compared with thought. Since the reader has not, like the writer, the whole subject in mind at the start, the first point, the point of approach, must be one that is satisfactory in itself; that is, one through which the reader can intelligently enter the subject. No more has the reader the whole subject in mind at any time till he reaches the end, and if the explanation is complicated, he probably has not then, for after five or ten points have been given, his mind cannot keep its grasp upon them in any such way as is possible for one who has perhaps long been thoroughly familiar with the subject. At each step the reader's

attention will tend to fly off and generally in a direction in which the writer does not want it to go; consequently the writer must not only stake out a definite single line of progress, but he must so choose it that he can hold his reader to it. In writing for specialists the line to be chosen is often one that has become a matter of habit for those who deal with similar subjects; but for readers who have not special knowledge of the subject — and it is with subjects addressed to such readers that we are now concerned — the only way is to follow a line of advance in accordance with habits of thought common to all.

51. How to determine the order of presentation. — In presenting the details of an explanation it is important to choose a line of development which will itself put as little burden as possible upon the reader. Suppose instead of leading our reader through a treatise in order that he might understand a line of thought, we were conducting him through a factory that he might understand how the work there was done. If we took him from room to room from the point where he happened to find us to the most distant part of the building, it would all be clear to us, but it might simply confuse him, for the arrangement of the work in the different rooms would be determined by principles of economy in operating not by principles of economy in explaining. If, on the other hand, even at the cost of some extra effort on our part, we were to take him first to the place where the raw materials were received, and show him how they came, the size, the shape, and kind of package ; then to the stock room and show him how the stock was stored, how catalogued, how brought out as needed ; then to the first machine that worked upon the stock, then to the second, and so on till we reached the finished product ready for shipment ; he would understand, not only when he finished his visit, but as he went along from room to room.

No general principles can be laid down which would be of much value in determining the order of presentation, for each case needs to be considered separately. Sometimes there is but one satisfactory order, often there are several. In all cases, however, that order should be chosen which at the start and at each step in the development gives the reader the maximum of understanding and the minimum of bewilderment as to the subject matter and as to the reason for the order of presentation.

52. **When the general conception should be given.** — It will be remembered that in the treatment of the transit which we have been considering (Appendix, Article I) the general structure of the instrument is explained before any of the construction details are presented. To many it seems more natural in technical writing to jump at once into details and to build up through them the general conception. The presentation of the general conception first seems to them unnecessary, undesirable because it involves repetition, and less practical than to begin with details without ado. In justification of beginning with the details two facts may be cited. First, the method of modern investigation and of laboratory practice is to start with many concrete cases and through a study of them to build up general laws. Second, engineering writing does, in fact, generally " get right down to the facts " as directly as possible. Two things, however, should be remembered : explanation is a different matter from investigation, and writing for the beginner is a different thing from writing for a specialist. Our problem at present is the writing of explanations for readers who are not yet specialists.

53. One of the serious difficulties in technical exposition, as we have seen (50), arises from the fact that the writer has the whole subject in mind and the reader has not. Consequently it simplifies the problem if the writer gives the reader at the start a general conception. Without

such a general idea, it may be as difficult for the reader to place the details properly as it would be for him to put up the finish, the plaster, or the gas pipes in a house before the frame was up. In fact it often happens that in order for the reader to get a real understanding of the subject the details of which are presented first, he must go through the whole subject with only partial understanding till he can build up for himself a general conception, and then, from memory or from re-reading, assemble the details. Even the man who invents a machine begins with general ideas. First he has a conception of the general purpose which the invention is to serve ; then he determines the general principle on which the machine is to work ; and only after these steps does he consider the working out of the details. Details do not have full meaning till they take their place in a general conception.

54. Recognizing this fact, we may accept the principle that the general conception should be given before the details in all cases except those in which it is safe to assume that the reader already has the general conception in mind. This general treatment should be as brief as possible. It should exclude all but the essentials in order to bring them out distinctly, and above all it should not anticipate details to be explained later. Such a general conception properly given makes the whole subject more comprehensible for the reader, and it actually makes the problem of expression simpler for the writer. He will find it much easier to build the various details into their proper places after the general idea is clearly presented.

PRINCIPLES OF DIVISION

55. In our discussion of the structure of the synopsis we have assumed that there would always be divisions. We need now to consider what general principles should determine the making of divisions. In writings of all

sorts we are familiar with the three main divisions: (1) Introduction, (2) Body, and (3) Conclusion. In literary description these divisions may be disguised ; in literary narration they generally do not appear as formal division in the writings of the present ; but in all forms of composition which undertake to carry the reader through a process of thought (4), they may be marked, and in formal argument they are absolutely essential. In technical writing they may not seem equally important. There must obviously be a Body, for by that we mean the whole explanation which the writing is to give ; the only question as to general divisions is, therefore, Should there also be an Introduction and a Conclusion? In addition to these general divisions, we need to consider the office of the Title and the character of the minor divisions.

56. **The Introduction.** — In many cases an Introduction may seem unnecessary. From the elementary training in English many get the notion that an Introduction is a roundabout and somewhat ostentatious way of starting, which adds a flourish, but serves no other purpose. To such it may seem one of the marks of the practical man to omit all Introduction and to go directly to the main task without ornamentation or verbiage. Certainly there can be no justification for a main division which is mere flourish.

57. Perhaps we can get the best idea of the purpose which the Introduction should serve by comparing the building up of a logical structure which the reader is to understand to the construction of a large office building. The Body of the paper corresponds to the actual building. But the building has to rest on something, the foundation. If the site of the building is chosen, as it usually has to be before anything more than the general character of the building can be planned, the foundation, in so far, is determined ; but the ground in its natural condition is

seldom suitable for actual construction. The building itself might be solidly put together, but if it had not proper foundation it would fall. Building the foundation is sometimes a costly process of driving piles or sinking caissons, sometimes it is a simple matter of building on bed rock ; but in all cases the first thing is to make over the site so that it will support the particular building to be erected. All the time and money thus expended which is not required for this particular building is wasted ; all that is required to build a solid foundation is as well spent as any that is put into the main construction. Now, the Introduction, in a similar way, is the foundation of the article to be written. If we are going to build a logical structure, we must first select our site, that is to say, the readers we are going to address. Writing without definite readers in mind is never effective. Yet we must recognize that this site (the knowledge and interests of those who are going to read what we have to communicate) will not make an adequate foundation. We must make it over so that it will support our special structure. This is the real and the only purpose of the Introduction.

58. In the explanation of the transit (25) the writer is addressing readers who know something of engineers and surveyors and of their work, and he brings his explanation immediately into relation with that assumed knowledge by the statement that "The instrument most used by surveyors and engineers is called a transit." But he recognizes that the reader's knowledge is not necessarily exact or complete, that he may, for example, confuse the transit and its uses with the surveyor's level and its uses. Therefore he removes the possibility of such confusion by giving the specific uses of the transit. In other words, he has made over the foundation which he assumes to be in the reader's mind so that it will support the particular structure he is to build.

59. Some subjects necessitate much work on the "foundation," others less. A reader who already knows the general subject thoroughly needs much less introductory explanation than one who is just entering that particular field. A chapter in the middle of a book often needs very little introduction. The preceding chapters may have so prepared the reader's mind that the next phase of the subject may be entered on directly. Yet there is at least the Title which prepares the reader for the contents of that particular chapter. We may say, therefore, that the Introduction may be reduced to very low terms, even so low as a single word (the Title), but it should never be entirely omitted, and it should do all that is needed to enable the reader to begin the Body with a mind ready to grasp the subject intelligently.

60. **The Conclusion.** — The Conclusion, even more than the Introduction, is in the conception of the imperfectly trained an ornamental flourish, something, indeed, like the "tail-pieces" with which printers used to decorate the blank space at the end of a chapter. For those who have in mind such ornaments, the best course, for a time at least, is to stop simply and directly when the end of the Body is reached. Often in a well-written piece of technical writing no Conclusion is necessary; when the last point of the Body is explained, the subject is manifestly finished and more words are but wasted.

61. In such cases, however, two points need to be carefully considered. In the first place, an abrupt ending is unfortunate. When a public speaker concludes so unexpectedly that we think for a moment that he has forgotten what he was going to say next, or when a caller rises to leave with awkward haste, the conclusion is not well made. So it is when a paper ends in such a way that if the last line happened to come at the bottom of the page we should turn the page expecting to continue. It is

well at least to prepare the reader. That often may be done by simple guide-post expressions, such as, "In the last place." It may be done much better many times by making clear early in the paper what the scope of the subject is and what steps are to be taken, and by then developing the treatment in such a way that as the end is approached the reader is fully aware of it. In the second place, if the subject is long and complicated, in all probability the more important parts will be treated first, then will come minor details, which may leave the reader with a confused or an ineffective impression of the whole. In such cases, though the subject may be said to be finished when the last minor detail is presented, the explanation is more effective if there is added something, a sort of assembling of parts, which leads the reader back to the conception of the whole. In each of these cases, there is no formal Conclusion added after the Body is finished; the finishing off of the subject is accomplished rather by the way in which the Body itself is shaped.

62. There are cases, however, where a formal Conclusion is needed. If we are getting our readers to go through a process of thought not only that they may understand it as a piece of reasoning but that they may apply it to some specific purpose or in some specific way, we may need to add something which will aid to this end after the explanation itself is completed. There are many ways in which this may be done advantageously, as we shall see when we turn to specific subjects. To use the figure of the office building again, the building itself, in as far as it corresponds to the Body of the writing, is the concern of the architect, the engineer, and the contractors; but after their work is finished, it may be necessary to do much more to fit the building for actual occupancy for specific purposes. We may say, then, that just as an Introduction is necessary to lay the foundation in the reader's mind

for a proper understanding of the Body, so, in any writing which is complete in itself,[1] it is necessary to round out the subject treated in the Body, either through the way in which the Body is shaped or by means of an added formal Conclusion, in order to give the subject as a whole real meaning and value for the reader.

63. **The Title.** — As we have already seen (59), the Title may serve as a part or even as the whole of the Introduction. Just what it should express we shall consider more fully in Chapter VIII (172–173). Here it will suffice to note the two somewhat different introductory purposes which it serves. As the heading of a chapter it simply indicates as far as is possible in a single word or a few words what the subject of the chapter is, that is to say, it takes the first step in shaping the reader's mind. As the heading of a whole piece of composition, a book, a pamphlet, or a magazine article, likewise it serves to define the subject in this preliminary way ; but it also acts as a guide-post from which the reader gets some notion whether or not this particular piece of writing is something he needs or wishes to read.

64. **Minor divisions.** — The Introduction, the Conclusion, and even the Body may be constructed without subdivision ; but if there is a long list of details, presenting them in the form of an unbroken sequence offers serious difficulties for the reader. The human mind can hold only a limited number of conceptions near enough to conscious attention to be able to deal with them effectively. Even if care is exercised, in presenting a long series of coordinate ideas, to connect each member with the preceding and with the following, after six or seven have been given, the reader who is getting first knowledge will find the earlier members of the series slipping from his mind. To

[1] It should be noted that a chapter may lead on to the next rather than stand complete in itself.

gain intelligent understanding he must stop and re-read. More than this, the monotony of such a list makes it difficult for him to maintain his interest and his attention. The writer should recognize these difficulties and so construct his subject as to remove them.

65. A hint as to a way in which this may be done is given by a common " memory test." Things of various sorts are displayed ; the contestants are allowed a limited number of minutes to inspect the articles, and then are required to withdraw and write down the names of as many of the things as they can remember. Those who have " learned how " know that if they *group* articles they can remember more. There may be ink, pens, pencils, erasers, and other articles for writing ; there may be thread, needles, pins, and other sewing articles; there may be certain fancy articles ; and so on. The mind can remember groups as easily as it can separate articles, and when it has recalled a group it can then recall the small number of individual things of which it is composed.

66. If a list of details in a piece of exposition is thus split up into groups, it relieves the attention of the reader and tends to keep his interest from flagging. Except in a short report or magazine note this is always possible. If a long list is carefully examined, it will generally be found that the members are not all coördinate. Certain parts of an instrument together form a unit which in the construction or the operation is distinct from the units which other parts make up. Certain steps in a process may be performed independently of other sets of steps. All of the details, it is true, may be conceived as coördinate parts of the whole subject, but proper subdivision brings out the relations between the different details more fully and gives a more thorough understanding of the subject, and at the same time the grouping of the facts makes it easier for the reader to follow the explanation, to keep

clear the exact point reached at each step, and to recall when necessary any parts already given.

APPLICATION OF THESE PRINCIPLES

67. In this chapter we have considered some of the commonest and most important problems of technical writing. To get a real understanding of their nature the engineer should analyze a number of examples of technical writing of different sorts. All that has been attempted here is to state the problems and to formulate general principles on which their solution should be based. Actual writing presents not general but specific problems. Each subject sets its special problems, and in part the personality of the writer should determine how he can handle the subject best. Above all, the method of treatment should always be shaped with the special readers addressed distinctly in mind. In all cases, however, it is best to start from general principles.

68. In the next four chapters we shall apply these principles to concrete cases: in Chapter IV to "The Transit," a sample of descriptive exposition; in Chapter V to "Measuring Horizontal Angles," a sample of narrative exposition; in Chapter VI to "The Molding of a Shaft Coupling," a sample of directions; and in Chapter VII to "The Vernier," a sample of exposition which combines description, narration, and directions. In each of these cases we shall not attempt to produce a model of technical writing of any practical sort, we shall rather apply the principles formulated in this chapter, simply to understand the theories more thoroughly and to test their value.[1] In Chapter VIII we shall summarize the results and study actual examples of technical writing in the light of the general principles for the purpose of getting practical suggestions.

[1] The synopses presented are the composite results of several years of theoretical study in class.

CHAPTER IV

DESCRIPTIVE EXPOSITION

Criticism of "The Transit" (Appendix, Article I), §§ **70–74**.
Criticism of "The Transit" (Appendix, Article II), §§ **75, 76**.
A synthetic synopsis of "The Transit," § **77**.
Principles special to description exposition, §§ **78, 79**.

69. In order to apply the general principles of technical writing to a single piece of descriptive exposition, it will be simplest to take the subject we have already analyzed (25), "The Transit." Since there are two treatments of this subject in the Appendix (Articles I and II) it will be advantageous to criticize them in the light of the general principles which we have formulated, before we undertake to build up a synopsis according to theory.

CRITICISM OF "THE TRANSIT" (Appendix, Article I)

70. In general this treatment is accurate, complete, logical, and economically presented. One point needs special consideration, *the use of illustrations for purposes of economy of presentation.* From Figure 46 the reader gets many ideas not given him in the text: the relative size of the parts, their shape, and much about their position. The entire omission of these details would undoubtedly lead to the reader's forming in his imagination ideas which would be erroneous; the verbal explanation of such minor points would be tiresome and would certainly obscure more important matters. Figure 47 serves an entirely different purpose. The most difficult part of the instrument to understand, the concentric sockets and axes, is carefully

explained in the text, then this explanation is reënforced by Figure 47 which shows that part of the instrument in vertical section.[1] In these two ways illustrations may be used to economize the presentation of most technical subjects.

71. The *structure* is logical so that it is possible to make a synopsis which does not violate the eight rules of form (40). The details are given in a logical order, for the writer starts at the top of the instrument and works down toward the bottom in a way easy to follow in the figure and simple to understand. The general conception is given first. The general structure is carefully yet briefly explained and, it should be noted, no technical terms are used here. The general method of using the instrument is also adequately explained. By the careful use of such general terms as "a given object," "a second object," and "at the point where the transit is placed," the writer keeps from getting involved in the problems which arise in explaining how to measure a given angle in the field (see Chapter V). In such ways as these a general conception may be presented in a few words and without anticipating details to be explained later.

72. In this treatment there is an *Introduction* and a *Body*, each with the general character which we have theoretically ascribed to these main divisions. There is no Conclusion, but there is no occasion for one, since this selection is but a fragment. Reference to the book from which this selection is taken would show that it is followed by other matter which is a part of the full explanation.

73. The *Introduction* defines the instrument in the way we have already analyzed (58). The distinction between the use of the instrument which requires no attachment and the uses which are made possible by the

[1] Unfortunately the figure is not placed where it is first needed and is not covered by letter references.

presence of attachments is serviceable for the beginner, since it brings out distinctly the fundamental use of the transit, which alone does not vary with make or style. The list of operations which may be performed is not complete : shooting in grade stakes, taking bearings, and doing the work of the solar compass at least might have been mentioned. Such a swelling of the list, however, would tend to overload the definition. If it is not considered well to make a complete list, the statement would be more exact were it to read, "and, with certain attachments, for" *such operations as* "measuring vertical angles," etc. The word "distance" is ambiguous, especially for the beginner. He might think vertical distance (vertical angles and vertical distance) was intended, and he might think it was distance in the general sense (along the surface of the earth). As a fact, horizontal distance, vertical distance, and distance along the line of sight (when between horizontal and vertical) may be measured with a transit. It is evidently distance along the line of sight that the writer has in mind, and probably the readers addressed would so interpret it.

74. A certain amount of *grouping of details* is introduced. The distinction in the Introduction between uses without and uses with attachments suggests a division in the Body, one part explaining the "plain" transit, the other the "complete" transit. That distinction is lost in the part giving the general conception and does not appear in the details of construction given in the Appendix. As a matter of fact, the whole Body here given deals with the plain transit, and sections following in the book take up the attachments of the complete instrument. It would have been helpful to the reader if at the beginning of the Body a term had been used which would have made clear that the writer was to explain first the plain transit. In giving

the general conception, the general structure is given by itself, then the general method of using. In the details of construction, the "parts" of the instrument are taken up, then the attachments necessary for operating these parts; but the two groups are not clearly enough distinguished so that the beginner would realize the difference. The long series of "parts" is given unbroken, when it would have been a simple matter to group them in a helpful way. The tripod and the leveling head are distinct groups of parts; so also are the two motions in the upper part of the instrument. These four divisions — the upper motion, the lower motion, the leveling head, and the tripod — might easily have been foreshadowed in the explanation of the general structure, then with a word in the details of construction to indicate each of these groups of parts, they would have been presented so that the reader would get a clearer understanding of the structure and would not be burdened by a long unbroken list.

Criticism of "The Transit" (Appendix, Article II)

75. In order to have the structure of the second treatment of "The Transit" clearly before us, it is presented in the following synopsis: —

THE TRANSIT

Introduction. The engineer's transit is the most useful and universal of all surveying instruments. It is

A. used:

I. to measure

1. horizontal angles,
2. vertical angles,

II. also to

1. read distances by means of stadia wires,
2. determine bearings by means of magnetic needle,

3. do the work of the solar compass by means of special attachment,
4. do leveling by means of bubble attached to telescope.

B. Therefore competent to perform all kinds of service rendered by any of the instruments heretofore described,

C. sometimes called the "universal instrument."

D. Shown,

I. in Fig. 17.

II. In sectional view through the axis (of different make) in Fig. 18.

BODY.

A. (Important parts and general method of using.)

I. (The most important parts of the construction are):

1. Telescope,
2. needle-circle,
3. vernier plates,
4. *means of rigid attachment of these three to*
5. inner spindle, which turns in
6. socket, *C*, Fig. 18.
   This portion of the instrument is called *alidade* as it is the part to which the line of sight is attached.
7. Horizontal limb (carried by socket *C*) shown at *B*,
8. *means of revolving in*
9. outer socket, attached to
10. leveling head,
11. proper clamping devices for making either or both parts rigid.

II. (General method of using transit):

1. (To read horizontal angles):
   a. Horizontal limb *B* clamped rigidly to leveling head,
   b. alidade spindle revolved,
   c. horizontal angle read by noting vernier-readings on the fixed horizontal limb for the different pointings of telescope.
2. (To find true azimuth of a line):
   a. Horizontal limb set and clamped so one vernier reads zero when telescope is on meridian,

b. telescope pointed at any other object,
c. same vernier gives true azimuth of the line.
3. It is therefore necessary to have two independent movements of telescope and limb on the same axis.

B. (Additional details of construction):
I. Magnetic needle, *N.*
II. Plumb-line, attached at *P.* (Should always be in the vertical line passing through the center of the graduated horizontal circle. This will be the case when it is attached directly to the axis itself, for this must always be made vertical.)
III. Graduations on limb from zero to 360°, sometimes a second set of figures to 90° or 180°.
IV. Two verniers on horizontal limb, 180° apart.
V. Shifting center (in both Fig. 17 and Fig. 18), enabling the final adjustment of the instrument over a point to be made by moving it on the tripod head.
VI. Telescope shorter than those in leveling instrument, in order that it may be revolved on horizontal axis without having standards too high.

Conclusion.

A. The instrument is called "transit" on account of this movement, which is similar to that of an astronomical transit used for observing the passage (transit) of stars across any portion of the celestial meridian.

B. Other types:
I. "*Theodolite*" with telescope too long to be revolved.
II. "Plain transit" without vertical circle or bubble attached to the telescope.

76. An examination of this second treatment of the transit shows that it differs from the first in three general ways: (1) it is addressed to the man who is using the instrument in the field rather than to the beginner; (2) it rests more directly on previous explanations of other instruments and processes; (3) the order in which the

facts are presented is determined by the suggestions of the separate facts rather than by any single logical plan. A few points will be noted under each of these heads.

(1) The definition here groups the measurement of vertical angles along with the measurement of horizontal angles as the essential uses of the instrument. This is a natural grouping for the man in the field, because as a matter of practice the process is essentially the same in the two cases and the user of the instrument commonly thinks of them together. On the other hand, this grouping does not bring out clearly the fundamental operation which every transit must be fitted to perform and which must be kept clearly in mind in order to understand the relation of the different kinds of transits. Although the construction details include only those of the plain transit, that instrument is not defined till the last sentence.

(2) The definition in this case gives a fuller list of operations which may be performed by means of attachments than is given in Article I, and names the attachment in each case (except one, A. II. 3) by which the special operation is performed. This makes the explanation more definite, provided the attachments are already known to the reader ; if they are not, it is wasteful and confusing to bring in technical terms where they cannot be explained. Introduction B makes it clear that in this case the reader is supposed to have received the necessary explanation in earlier chapters of the book. By the naming of these special attachments and by the statements in B and C of the Introduction, this treatment brings out the relation of this instrument to other surveying instruments more fully than the first treatment (Article I) does.

(3) The logical structure of this article is less easy to grasp. The method seems to be to state the parts of the instrument which are essential for measuring horizontal angles, to explain briefly how they are used, then to bring

in other details. But the differentiation between A and B of the Body is not carefully made, and B is neither complete nor systematically arranged. It was evidently the purpose of the writer to mention those parts which it is important for the reader to understand, but because of the apparent lack of plan in introducing the details, some (such as Body A. II. 3) seem like after-thoughts, and others (such as Body A. I. 2 and Body B. I. giving the compass, and Body A. I. 3, Body A. II. 2. *a*, and Body B. IV. giving the verniers) in part say the same thing twice or three times. No distinction is made between the general structure and the details of construction ; there is no grouping of parts, and there are few references to the figures given.

A Synthetic Synopsis of "The Transit"

77. In building up a synopsis on the subject of the transit, we shall, as in all cases in the first part of this book, address the beginner and attempt to give an explanation which will assume as little knowledge of surveying instruments as possible in order that this treatment may be practically complete in itself. We shall deal mainly with the plain transit, explaining only the most important of the attachments and their uses by brief suggestion. Since in shaping our synopsis in these ways we are following the same course as adopted in Article I, we shall copy the synopsis already given (25), except that we shall undertake to apply our principles in all cases.

THE TRANSIT

Introduction (Definition). The transit is the instrument most used by surveyors and engineers,

- *A*. for measuring horizontal angles,
- *B*. with certain attachments, principally,
  - I. for measuring,

1. vertical angles,
2. distance,
   a. along the line of sight,
   b. of rise in a hundred feet,

II. for determining magnetic bearings,

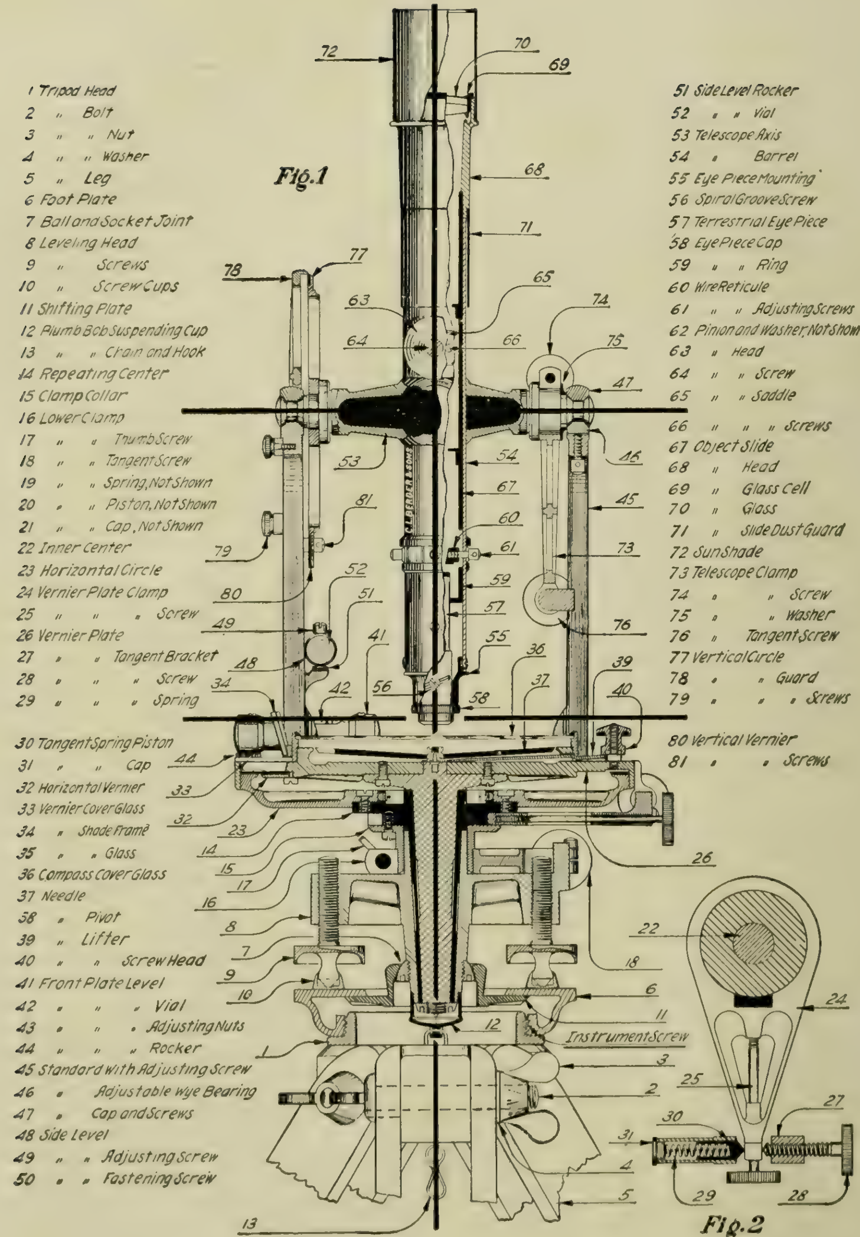
III. for leveling.

Body. (Construction of the instrument.)

A. The transit without attachments, the "plain transit."

I. (General structure and method of using.)

1. (General structure.) It consists of
   a. the upper motion, consisting of
      w. a telescope, for sighting from the vertex along the sides of the angle,
      x. a means of attachment to
      y. a pointer, which has
      z. means of movement around
   b. the lower motion, consisting of
      x. a graduated circle,
      y. means of clamping the lower to the upper motion that they may be moved together,
      z. means of clamping the lower motion to the
   c. leveling head, means for making the instrument level, resting on
   d. the tripod, which supports the instrument at a suitable height.
2. (General method of using.)
   a. The upper and lower motions are clamped together,
   b. the two are revolved till telescope points at a given object,
   c. the graduated circle is clamped to the leveling head so it will not revolve,
   d. the upper motion is then unclamped from circle and
   e. turned till the telescope points at a second object.
   f. The number of degrees of the circle over which the pointer has passed will be the angle subtended at the point where the transit is placed by the two objects seen through the telescope.



CROSS SECTION OF THE BERGER TRANSIT.

The heavily drawn center line and the two parallel lines drawn at right angles to it in the above cut indicate conditions required in a perfectly adjusted transit.

II. Details of construction.
1. The upper motion consists of
   a. the telescope, 54–72, Fig. 1,
   b. horizontal axis, 53, by means of which telescope is revolved in a vertical plane,
   c. bearings, 75, on which axis rests on top of
   d. standards, 45, rigidly attached to
   e. circular plate, 26, which carries the
   f. pointer, which is the zero mark of a vernier, 32 (usually two double verniers, 180° apart).
   g. two level tubes, 42, 48, on vernier plate to show, when adjusted parallel to plate, whether plate is level,
   h. conical axis, 22, on which plate revolves, made by maker perpendicular to plate, so when plate is level, axis is vertical.
2. Lower motion consists of
   a. conical socket, 14, inside which fits the conical axis of upper motion, which socket is the inside of
   b. conical axis of
   c. the plate, 23, which carries
   d. the graduated circle.
3. Leveling head consists of
   a. a hollow conical spindle in which the conical axis of the lower motion revolves, which spindle connects
   b. top plate, 8, and
   c. bottom plate, 6,
   d. leveling screws, 9, to level upper plate,
   e. screw (marked "instrument screw") to attach the lower plate to
4. Tripod, 1.
5. Attachments for operating parts.
   a. Cross hairs, Fig. 3, at the focal point of the object lens to aid in sighting.
   b. Clamp, 24, Fig. 2, fastening vernier plate to limb plate,
   c. Upper tangent screw, 28, by means of which the vernier plate may be moved a slight

amount after clamped by screw, 24, so the vernier may be set at a given reading or the telescope pointed more pre-

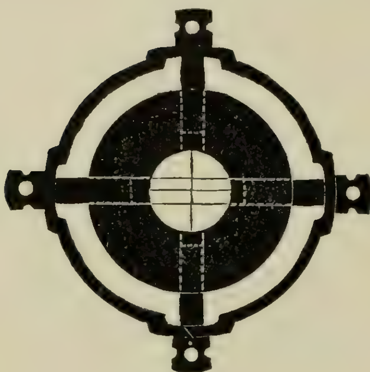


Fig. 3.

cisely than would be possible turning the alidade by hand.

d. Clamp, 16, Fig. 1, to attach to the lower motion to the leveling head.

e. Lower tangent screw, 18, to make possible slight movements of the limb after it is clamped by the screw 16.

f. Ring or hook, 13, fastened to the center of the lower part of the leveling head from which a plumb line may be suspended to set the instrument over a point on the ground.

g. Shifting center by means of which the transit may be set exactly over a point, consisting of

y. a plate, 7, attached to the base of the spindle of the leveling head and extending under the plate which is screwed on to the tripod through

z. a circular hole large enough to allow movement about the center of the top of the tripod, when two adjacent leveling screws are loosened.

B. The commonest attachments for other uses of the transit.

I. A device for measuring vertical angles in a way

similar to that in which horizontal angles are measured, consisting of

1. a vertical arc, 77, attached to the standards,
2. vernier, 80, attached to the axis of the telescope,
3. clamp, 74, and
4. tangent screw, 76.

II. A pair of horizontal wires, Fig. 3, in the telescope one each side the horizontal cross hairs known as stadia wires, for reading distance along the line of sight.

III. A graduated head, known as the gradienter, on the tangent screw, 76, by means of which very small vertical angles may be set off representing so many feet rise or fall in a hundred.

IV. A magnetic needle, 37, with a graduated circle for taking bearings.

V. A level tube under the telescope to enable the instrument to be used as a level.

Conclusion. (Different kinds of instruments — only suggested here for the sake of brevity.) Transits

I. are of different makes, each being specially adapted to certain purposes.

II. Differ in possible accuracy, and so are adapted to work of different degrees of precision.

III. Will do, with the various attachments, a greater variety of field work than any other surveying instrument.

Principles Special to Descriptive Expositon

78. No attempt has been made in this chapter to shape a practical treatment. If technical subjects were regularly developed as fully as "The Transit" has been here, textbooks would become impossible to use on account of their size. In writing a textbook, some points would be omitted on the ground that the readers had become familiar with them before beginning a study of the transit, and others, in order that they might be taken up later in other connections. Much would be left for the teacher to

add in class or for the students to work out themselves. But even the full treatment given here would take up much less space in a final writing. Facts which here are spread over a half dozen lines would in the final form be expressed in one short sentence. Repetition which the form of the synopsis necessitates (28, Rule 5) and the explanatory expressions which are placed in parentheses would all be omitted in the final form. It should not be overlooked that all that has been attempted here is to gather together all the facts and to express fully the relations between those facts.

79. If we take this subject as typical of descriptive exposition, we can formulate as the result of our study certain special principles additional to those given in the preceding chapter. The *Introduction* defines the object which is to be described. In this case the definition consists of a statement of the uses of the instrument. The *Body* performs three functions which may be at least considered separately. 1. It names all the parts, or all those which it is advantageous for the reader to consider. 2. It describes each part, either by reference to a suitable figure (as the "tripod" is explained in the above synopsis) or by words and reference to the figure (as the "pointer" is explained). 3. It explains the relations of the parts to one another so that the reader will understand how they work together. The *Conclusion* in this case "opens up" the subject, that is to say, after the Body has explained a single style of transit with a few of the commonest variations, the Conclusion suggests something of the variety of instruments on the market, their different uses, and their relation to the other instruments of the surveyor. Aside from these additional points, descriptive exposition, as far as our study has shown, is shaped entirely by the fundamental principles.

CHAPTER V

NARRATIVE EXPOSITION

The three main divisions, §§ **81–83**.
Two problems heretofore not fully considered, §§ **84, 86**.
Three new problems, §§ **87–93**.
Synopsis of "Measuring Horizontal Angles in Surveying," §§ **94–99**.
Special problems of "Measuring Horizontal Angles," §§ **100–105**.
Summary of principles special to narrative exposition, § **106**.

80. The commonest form of narrative exposition is the explanation of a process, and since most of the problems of narration which are special to the writings of the engineer may be found in such a piece of exposition, we shall limit our study for the present to that form. In this chapter we shall consider only a single subject, and, inasmuch as the principles which underlie narrative exposition are largely the same as those underlying descriptive, the best way will be to begin by applying to our new subject the conclusions which we have already reached.

The Three Main Divisions

81. The Body. — The Body of a paper dealing with a process will naturally contain the explanation of that process, and on general principles it should contain the whole process and nothing else. None of the steps should be anticipated in the Introduction and none should be left for the Conclusion. Stated thus in general terms, this principle seems obvious enough, but we shall find that it will give us grounds for settling at least one question which in some cases is important (90).

82. The Introduction. — If we are to judge from what we have discovered thus far, the Introduction should be a definition ; but the question arises, Definition of what? Clearly not a definition of the process, in the sense of showing of what the process consists : that is, what makes up the Body. What needs definition in the Introduction is rather the thing which the process is to accomplish. In other words, the Body is the solution of a problem, the Introduction is the definite statement of that problem. The Title may, and generally should, suggest the problem ; the Introduction should give the reader a precise idea of what it is.

83. The Conclusion. — In narrative as well as in descriptive exposition, there may be no need for a Conclusion. When the last step in the process is finished, there may be nothing more to say. In such cases, however, as we have seen (61), the Introduction and Body should be so planned that the reader knows without doubt when he is approaching the end and has a realizing sense at the end that the subject is completed. On the other hand, in all cases where the explanation of the process is in any way a course of abstract or generalized reasoning, the explanation is usually not brought to a satisfactory end when the last step in the process is reached. If the reader is left at the end of the Body without a clear idea of what part that process plays in his actual or possible experience, he should be given in a formal Conclusion some idea of the application of the process.

Two Problems Heretofore Not Fully Considered

84. Determining the scope of the treatment and the amount of knowledge which it is safe to assume the reader has. — In shaping the general structure of a piece of technical writing, two questions should be settled at the start. The writer must decide how much, if any, special knowl-

edge he is warranted in assuming his reader to have ; and he must also decide how broad and how detailed a treatment of his subject it is wise under the circumstances for him to give. To one who has thought over his problems in writing, these may seem too obvious to need special mention ; but often they are hard to answer, and many of the serious defects in the writing of engineers are due to failure to consider these questions duly or to follow a decision once made consistently. It is early in our study as yet to consider such complicated questions fully. For the present it will be enough to answer them for the single case which we are to study in this chapter : " Measuring Horizontal Angles in Surveying."

85. As to the scope of treatment in this particular case, we must recognize that many things might well be said on the subject of measuring horizontal angles, and would inevitably be said or observed in the course of long experience in surveying, If, however, we give a general conception of the method, such as one must have before beginning the actual use of the instrument, and suggest some of the other possibilities, leaving out all the finer points which would be learned gradually from experience, we set ourselves a fairly definite limit. In an important way our treatment will be different from those given in textbooks. Part of the process of measuring angles the student would naturally have learned previously in other connections, consequently the textbook treatment of this subject would with reason omit such matters. That would leave the explanation, taken by itself, incomplete, and in order to study the problems of logical structure as a matter of theory we wish to give each subject logically complete treatment. We shall, therefore, attempt to treat each step in the process equally completely.

86. To determine the amount of knowledge which it is safe to assume the reader has is a simple matter in the case

of "Measuring Horizontal Angles." He must know the general structure of the transit and the method of taking a reading with a vernier, and he does not need any other special knowledge. If we assume, therefore, that our reader understands verniers and the transit as it has been explained in Chapter IV, we have very definite grounds to start upon.

Three New General Problems

87. **Abstract or concrete explanation.** — Measuring a horizontal angle in the field is always a concrete process dealing with an angle marked in some definite way. In explaining the method, however, it is possible to present the case abstractly, considering any angle, that is to say, the intersection of two lines merely indicated by letters. Hence, in writing, the question arises whether it is better to deal with the subject in this abstract fashion or to present it as a single concrete case. With some subjects this question is important and difficult to settle, but in explaining the measurement of horizontal angles it makes little difference which course is followed. It will be better, therefore, to leave the discussion of the principle involved till we reach a subject where the problem is more important (129). In the meantime we may determine our choice in this instance arbitrarily in favor of the concrete explanation.

88. **Handling different methods of performing the same operation.** —If the process we are explaining can be performed in more than one way, the question arises as to which way should be explained first. In some cases it is possible to combine the ways, that is to say, to explain all the methods of taking the first step, then all the methods of taking the second step, etc. In such cases the question is whether it is better to combine or to give each process separately. This latter question must be

answered with due consideration of the specific process to be explained and of the kind of reader addressed. The answer should also depend somewhat on the way in which the writer himself finds it more natural to work out the problem, for, other things being approximately equal, it is always safer for a writer to follow a course natural to him even if it is not quite so natural for others. We should observe, however, that for the beginner it is simpler and more satisfactory to get a whole idea (an understanding of one way of performing the whole process), then to add other ideas on to that, than it is to carry along a complicated process of explanation for some time before a really complete idea is formed. If the methods are similar in some ways, it does not entail repetition to take up each separately, for it is possible to say of the second method, " It is the same as the first, except — " and this gives the writer the opportunity to emphasize the peculiar features in each method. To formulate a general rule of procedure in such cases, it is safe to say that if the differences between the methods are slight and affect only minor parts of the process, it is better to carry on the whole explanation as a single development ; but if the differences are many, important, or such as to require extended explanation, it is better, especially in addressing beginners, to take up one whole method at a time. If that is done, it is natural to choose for the first the one which is commonest ; but in as far as it is possible, it is better to choose that one which will seem to the reader simplest, or that one which will best serve as a type from which the other methods may be looked upon as variations.

89. **Descriptive matter in narrative exposition.** — Almost every process calls into use certain implements which need to be described. In addition, some of the circumstances under which the process is carried on may need

description. The question arises, therefore, Where in the development of the explanation of the process should this descriptive matter come? It may come in the Introduction or it may come in the Body at the place or the places where a knowledge of the descriptive facts is required in order to understand the process. Something may be said in favor of each of these methods.

90. Since the descriptive matter is no part of the process, in the strict sense of that term, but is of the nature of preliminary explanation which must be given in order that the reader may follow the real subject intelligently, it should, according to the distinction we have made 81, also 58), be given in the Introduction, not in the Body. Yet if much descriptive matter is put in at the start, it is wearying to the reader, just as long descriptions of characters or scenes are when introduced at the beginning of a story. Then, too, if the writer puts in detailed descriptions at the beginning, the reader, knowing as yet nothing of the process, gets little real value, and consequently forgets much before he reaches the place in the process where he finds use for the information. When a technical term which was fully explained in the Introduction is not used in the process till well along in the Body, the reader may even forget that the term has been mentioned before.

91. To explain an implement at the point in the Body where it is first used in the process, or the circumstances under which the process is carried on at the point where an understanding of the facts is essential, is a natural method. If the information is given the reader at the very point where he needs it, he is sure not to forget it. On the other hand, if descriptive explanations are brought in during the explanation of the process, they interrupt just as seriously as descriptions of characters or of scenes do if given in the midst of absorbing narration. What is

more serious, if the description is long or if it demands careful attention, the reader may, by the time he gets back to the narrative part, be confused as to the stage of the process he has reached.

92. In many cases the problem of where to introduce descriptive matter in narrative exposition is a serious one if we are aiming at the most effective presentation and not merely at one which it is easiest to give. Different subjects naturally lead to different solutions, but certain general principles may be laid down. In the first place, descriptive matter should always be cut down to the smallest amount consistent with clearness. Often it may be left out of the text entirely and given only by illustrative figures. For example, if the explanation of the process is carefully handled, an implement used at a certain point may need only mention by name in the text, provided a figure to which reference is made is inserted at the point where the implement is mentioned. Descriptions which can be given by figures or by a few words of explanation do not interrupt the narration seriously and therefore may be introduced at the point where they are most needed and where they run no risk of being forgotten. Complicated implements, a thorough understanding of which is essential, cannot be handled thus simply, and if they are fully explained in the midst of the process the digression will form a serious interruption. Generally it will be found that such descriptive matter may be given at the beginning as an important part of the Introduction ; and if the facts are properly presented, the value of the explanation will not be lost in the Body.[1]

93. In the case of "Measuring Horizontal Angles," the only special implement used is the transit, an understanding of which is assumed (**86**). If we were giving an "abstract"

[1] An illustration of descriptive matter inserted both in the Introduction and in the Body is given in the following chapter (**119**, **120**).

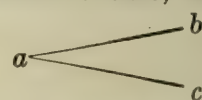
explanation (87), the angle would need mention only, because it would be nothing but the intersection of imaginary lines determined by lettered points. In the explanation of a concrete case, however, it is necessary to introduce a few words of description to make clear how the points determining the lines are marked. That description should be given in the Introduction.

Synopsis of "Measuring Horizontal Angles in Surveying"

94. **Introduction.** Applying the principles which we have formulated we get the following synopsis of the Introduction: —

MEASURING HORIZONTAL ANGLES IN SURVEYING

Introduction. (Definition of the problem.) To explain the ordinary methods of measuring horizontal angles in surveying, we may take a concrete case, an angle,



A. Which has been marked by
- I. a stake driven in the ground at the vertex *a*, having on top a tack to show more exactly the intersection of the two lines, and
- II. a pole plumbed on each of the lines to determine the direction of the lines,

B. Which is to be measured with a transit.

95. At this point we might consider our Introduction finished, and for many subjects such a direct statement of the problem to be solved is enough. Often, however, it is advantageous to add what may be called an *analytical definition*, that is to say, one which will analyze the problem into its component parts. By so doing we may give the reader a more exact idea of what the problem is and, by suggesting the main steps in the process, lay before him something like a general plan of the treatment to be given. If the process is simple, such an analytical defi-

nition would cost more than it is worth ; but if the process is complicated, a careful preliminary explanation of this sort will greatly benefit both writer and reader. For the writer it lays out the work so that he cannot easily overlook a step, treat one part less fully than another, or fail to follow the best order or the same order in explaining different methods. To the reader it gives a general grasp of the whole subject at the start and an outline of the process by which he can check off the steps as taken, so that he has something of the advantage of one already informed.

96. Such an analytical definition is easily framed for the subject we are considering, and though it may not be needed in such a simple process, it will serve to bring out what there is common to the different methods. It would be added to the Introduction as division C, as follows : —

> *C.* Which may be measured in various ways, in all of which it is necessary
> I. to set the transit exactly over *a*,
> II. sight *b*,
> III. sight *c*,
> IV. read the angular distance the vernier has moved on the limb.

97. **The Body.** — If we now turn to the Body, we find that it is in part outlined by the divisions under C of the Introduction. The process must inevitably be explained in the four divisions given there, and since the order in which the divisions are presented in the Introduction is logical (following as it does the order of the actual process) it should be strictly adhered to in the Body. Since there are several methods of measuring angles, the question arises whether they should be explained separately or combined (88). In this case the methods will be presented separately in order to give the reader a conception of the whole process as simply and as directly as possible and in order to emphasize the main differences

between the methods. The general outline of the Body will then be as follows: —

Body. (Details of the process.)

A. One method.

- I. Setting up over *a.*
- II. Sighting *b.*
- III. Sighting *c.*
- IV. Reading the angular distance on the limb.

B. Another method. The same as the first, except:

- I. Setting up (differences, if any).
- II. Sighting *b* (differences, if any).
- III. Sighting *c* (differences, if any).
- IV. Reading angular distance (differences, if any).

C. Another method. (Explained in the same way as under *B.*)

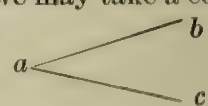
D. Another method (if any).

98. **Conclusion.** — Our paper will be concluded in the general sense, it is evident, when the last step of the last method is explained; and if the explanation is worded carefully, the reader will feel no abruptness or lack of finish if the paper ends at that point. Nevertheless it is possible to "apply" the information given in the Body by suggesting something of the variety of occasions on which surveyors and engineers have to measure horizontal angles. In this way the information given in the Body will be brought into more satisfactory connection with the general knowledge of the reader and with the work which in the future he may have to do.

99. **A complete synopsis.** — We are now ready to construct a complete synopsis as follows: —

MEASURING HORIZONTAL ANGLES IN SURVEYING

Introduction. (Definition of problem.) To explain the ordinary methods of measuring horizontal angles in surveying, we may take a concrete case, an angle,



A. Which has been marked by

I. a stake driven in the ground at the vertex *a*, having on top a tack to show more exactly the intersection of the two lines, and

II. a pole plumbed on each of the lines to determine the direction of the lines.

B. Which is to be measured with a transit.

C. Which may be measured in various ways, in all of which it is necessary to

I. set up the transit exactly over *a*,

II. sight *b*,

III. sight *c*.

IV. read the angular distance that the vernier has moved on the limb.

Body. (Details of the process.)

A. One of the common methods.

I. The transit is set over *a*,

1. roughly by manipulating the legs so that the instrument will stand,

a. over the point of intersection,

b. level,

c. at a convenient height,

d. firmly enough so the legs will not be moved by the wind or by a slight shock;

2. exactly, by

a. loosening two adjacent leveling screws and moving the shifting center till the plumb bob is brought exactly over the tack,

b. tightening these screws again,

c. leveling by

x. turning the alidade till one bubble tube is parallel with two diagonally opposite leveling screws,

y. turning these screws in the appropriate direction till the bubble is centered,

z. turning the other pair of screws till the other bubble is centered.

II. The first line is sighted by

1. setting the vernier zero exactly opposite the limb zero,

2. clamping alidade and limb,

3. unclamping limb from leveling head (if clamped),

4. moving alidade and limb till one of the markers (the one to the left according to custom) is sighted,
5. clamping limb to leveling head,
6. bringing the vertical cross hair into exact bisection of the marker by use of the lower tangent screw.

III. The second line is sighted by
1. unclamping the alidade,
2. sighting the second marker, approximately,
3. clamping alidade to limb,
4. making exact bisection as before except that the upper tangent screw must be used.

IV. The angular measurement — that is, the number of degrees and minutes the vernier zero has passed from the limb zero — is found by
1. reading "the whole number" directly on the limb, and
2. adding to that the "fractional part" given by the vernier.

B. Method when the vernier is not set at limb zero at the start, a method often used, particularly in reading angles about a single point. This method is the same as the one just explained, except:

I. The position of the vernier zero on the limb must be read accurately before the alidade is unclamped from the limb to sight the second line.

II. In obtaining a reading of the angle,
1. The reading taken before sighting the second line has to be subtracted from the reading taken after sighting the second line.
2. If the vernier zero passes the 360° mark on the limb in its movement from the first reading to the second, 360° must be added to the second reading before the first is subtracted.

C. Azimuth method. (Omitted here for the sake of brevity.)

D. Methods used for more precise work. Same as the above (*A*, *B*, or *C*) except:

I. In setting up the instrument,
  1. after the process of setting up as previously explained is completed, each step is repeated to see that the leveling has not affected the centering, or *vice versa;* and any inaccuracy detected is corrected.
  2. The alidade is slowly revolved 360° to see if the bubbles stay centered throughout the revolution; and any inaccuracy thus discovered is corrected.

II. In reading the position of the vernier a reading glass is used.

III. In measuring the angular movement:
  1. If the angle is narrow, its supplement is read and subtracted from 90°, or
  2. both "inside" and "outside" angles are read and added to see that the sum equals 360°.
  3. Often the reading of the angles is repeated, that is, after the reading is found as above,
    a. it is read repeatedly from left to right: —
      v. with upper motion clamped and lower unclamped, the left marker is again sighted;
      w. with lower clamped and upper unclamped, the right marker is sighted;
      x. again the left is sighted as before;
      y. and so on till a reading of about 360° is obtained.
      z. This resultant reading, divided by the number of readings, gives an average which is more exact and which, covering the whole 360°, eliminates errors of graduation.
    b. Next, the telescope is reversed and readings taken similarly from right to left.
      y. The average of this right-to-left average with the left-to-right average previously obtained eliminates errors due to clamping and unclamping and personal mistakes in setting,

z. and the reversing of the telescope eliminates errors of adjustment.

c. Both verniers are read in each case and averaged to eliminate the effect of eccentricity of vernier.

CONCLUSION. Horizontal angles are measured

A. roughly, in such cases as ordinary farm surveying,

B. with greater accuracy, in such cases as the staking out of city lots,

C. with the highest degree of accuracy, in the triangulation of the Government Geological and Geodetic Surveys.

SPECIAL PROBLEMS SUGGESTED BY THE SYNOPSIS

100. A much *fuller treatment* of the methods of measuring horizontal angles is presented here than is given in textbooks. When the subject is studied as a part of surveying, the different methods and applications are taken up in different connections and at different times as the student gradually gets experience. On the other hand, much more might be said and must be learned at some time by the expert transit man; and furthermore, each transit man has his own ideas as to the best methods for different occasions. The attempt has been made here to take a middle course, to give a general conception of the process which is logically complete yet as brief and simple as possible.

101. Body, A. I, the *setting up*, especially may seem unnecessary. In textbooks the common practice is to say simply, "Set the transit over the vertex of the angle." Since the learner would undoubtedly have had practice in "setting up" before he undertook to read an angle, it is logical enough to cover the whole of that part of the process by the technical term. Here, however, we are striving to give a treatment that will stand on its own legs; that is to say, that will be logically complete without depending on the reader's having any special knowledge except of the structure of the transit. Such being the case, the setting up of the transit must be explained as fully and as carefully as the sighting or the reading of the angular distance.

102. In explaining the method of setting up, it is an advantage to divide the process into two parts: "setting up *roughly*"

and "setting *exactly*," for it is important to impress upon the beginner just how much can be done to advantage, and therefore should be done, by the manipulation of the tripod legs, before it will pay to attempt to use the shifting center and the leveling screws. How much it is advisable to explain under A. I. 2 of the Body (the exact setting) is open to question. The attempt has been made here to indicate the degree of accuracy necessary for ordinary work and to leave for D. I the explanation of the checks which are applied in more precise work.

103. It is the aim to give the *simplest method at the start*. The one selected (vernier zero and limb zero in coincidence at the start) is in reality no simpler than the second method, where two readings are taken, and in such cases as reading all the angles about a point (as in a triangulation net) it is not so simple. To set the vernier accurately is about as difficult as to take a reading of equal accuracy. To the reader, however, it seems more simple to take one reading only, and on the ground that we must consider the reader and not the man familiar with the use of the instrument, it is better to start with the method here given first.

104. In the rest of the process care has been taken *to give all the steps*, to state definitely each time when a motion is clamped or unclamped, and to mention in each case which tangent screw should be used. In a paper for more advanced readers it would be needless to mention these details, for a real understanding of a transit would enable one to keep clear what free motion is permissible at each step and which tangent screw should be used. But the beginner needs to think these things out carefully. When he is first using the transit, he is not at all sure to clamp the right motion or to get his hand on the right tangent screw every time, even with the instrument before him to correct his ideas when they are wrong. In thinking out the subject there is no such means of checking, and it is important that the beginner should make complete statements at the start in order that misconceptions may be detected and corrected.

105. In Body, A, the *divisions* between I, II, III, and IV are somewhat arbitrary. The principle of division adopted here is to call each step complete when everything necessary to that step is done, leaving any following act as a part of the next step. For example, it is common to combine the setting

of the zeros in coincidence with the setting up of the instrument, but it is obvious that the transit may be completely set up without paying any attention to the position of the zeros, and the second method explained in the synopsis is different from the first, not in the setting up, but in the sighting of the first line. For these reasons it seems more logical to include the setting of the vernier (or the taking of the reading) in the second step, "sighting *b*." Again, at the end of II, we might mention that the alidade is unclamped, and so begin the sighting of the second line with, "Sighting the second marker"; but the sighting of any point is complete without unclamping. Whether the alidade is unclamped or not does not depend on what has been done in sighting the point; it depends on what is to be done next, as we see in the method of repetition, explained in D. III. 3.

Summary of Principles Special to Narrative Exposition

106. The problems which arise in narrative exposition are more varied and more complicated than those of descriptive exposition. All that has been attempted in this chapter is to make a thorough study of a single case. We have found three new problems: (1) Should the explanation be abstract or concrete at the start? (2) How should different methods of performing a single process be handled? (3) Where should descriptive matter be introduced in narrative exposition? The order of presentation in narrative exposition seldom offers any difficulties; whether it is the explanation of a simple process, such as measuring horizontal angles, or a long historical narration, such as an account of the development of the use of concrete, the order to be followed is that in which the separate steps were taken or should be taken in order to perform the process in the best way. The principles which our study of "Measuring Horizontal Angles" has led us to formulate will be applied to various special cases in the following five chapters.

CHAPTER VI

DIRECTIONS

Problems special to directions, §§ **108–113.**
Synopsis of "Directions for Molding a Shaft Coupling," §§ **114–122.**
Summary of principles special to directions, § **123.**

107. In writing directions it may be necessary to describe such things as are to be used, but in the main directions are narrative, since they deal with things to be done. Consequently any of the problems which we have considered in Chapters IV and V may arise in writing directions. In addition there are certain special problems which need brief attention.

Problems Special to Directions

108. **The form of the verbs and the attitude of the writer.** — The peculiarity of directions which strikes the attention first is that the verbs, instead of being in the indicative mode as they are in the case of description and narration, are, most of them, in the imperative. This is not merely a difference in grammatical form; it is a difference in attitude. When the foreman in a factory is telling a new operative how he is to run a certain machine, his attitude toward the man and toward the machine is quite different from what it is when he is explaining the operation of the machine to a visitor.

109. Explanation may not attempt to give the information necessary for one who is to do a certain thing; its purpose is simply to make the one addressed understand the process. Directions may or may not attempt

to make the one addressed understand the process ; but they should give him the information he needs in order to do the work. A new foreman may be instructed so that he knows how all the processes in the shop are carried on, though he may have no thought of doing any of the work himself. The unskilled laborer may not understand why he is putting together two parts of sand and one of cement in one case and three parts of sand and one of cement in another ; but he must be directed so that he will do the work right. Explanation often dwells on the very things which directions pass over, and *vice versa.* In explaining a machine, it may not be necessary to say much about the size of the parts or the materials of which they are made ; the principle of the machine is the important thing. In giving directions for making such a machine, knowledge of the principle of the machine may very probably be assumed ; at any rate, the dimensions, materials, and so forth must be fully given. If we examine the usual textbook explanation of voltmeters and ammeters, we find that they are presented by means of symbolic diagrams which make clear the electrical and magnetic conditions, but which give no idea at all, it may be, of the actual form, size, or physical arrangement of the parts, such as directions for making such meters would have to make clear.

110. Some writers shift back and forth from the indicative form of explanation to the imperative form of directions for no other reason than that for the moment the one form or the other seems to them an easier means of expressing the idea. It should be remembered that the two represent a real difference in attitude, and that there should be no change from one to the other unless there is a change in attitude.

111. **Need of keeping the reader continually in mind.** —The writing of adequate directions is often difficult, for

the reason that the writer has been long familiar with the process which he is trying to tell another how to perform, while the one addressed may have had no experience of that sort ; it is hard for the writer to realize the limitations of the reader. Many times in the sick room there is trouble because the one in charge of the patient does not know how to do something which the doctor did not consider needed mentioning. In order to write adequate directions, the only safe way is for the writer to go through the whole process in his imagination, step by step, taking care not to omit a necessary step or to do a thing otherwise than as his directions call for, until he learns instinctively to put himself in the reader's place.

112. **Handling matters of judgment and matters of skill.** — Two special cases, which are often overlooked, need careful attention in writing directions. In the first place, in almost every operation, there are points at which it is permissible or necessary to use judgment : to cut the pattern according to the cloth, to arrange machines according to floor space. In order to do this one needs good judgment, and no amount of directions will give this. Often, however, the directions do not make it as clear as the writer thinks where judgment may be used ; the reader may even be seriously distressed at such points because he thinks the writer has failed to tell him exactly what he should do. It saves doubt and hesitation if by hint, or by full explanation when necessary, it is made clear what points judgment should determine. In the second place, parts of many operations require special skill. That again cannot be given by directions ; it comes only from experience. But it is important to make clear to the reader that skill is necessary, and it is generally well to give some test by which success may be measured.

113. **Value of adding explanation.** — As we have seen (109), directions do not necessarily entail explanation ; but

whenever the person addressed is able to think for himself in relation to the work he is to perform, he wants to understand what he does. For several reasons it is better to make the meaning of the process as clear as possible. In the first place, if the one addressed really understands why he does what he does, he is much less apt to forget or confuse the process than if he is following directions blindly. It is only the lower grades of laborers who can work economically without exercising their own intelligence. In the second place, if the reader is given the reason for the various steps he takes, he will be much less liable to assume mistakenly that he can work out a better or an easier way. In the last place, if the reader does not obey directions correctly when they have been accurately given and sufficiently explained, the responsibility is entirely on him, not on the writer of the directions.

A Synopsis of "Directions for Molding a Shaft Coupling"

114. In order to study in detail methods of writing directions, we shall take as our subject: "Directions for Molding a Shaft Coupling." This subject offers many small matters of arrangement to consider, yet the process itself is simple to understand, and such directions may be given that the ordinary reader could follow them and produce results as satisfactory as could be expected from one who had not had experience.

115. **The Body.** — The Body of the paper will inevitably contain the directions for molding from a pattern of a shaft coupling. It should not have anything to say about any process which precedes or follows the actual molding. Since we are dealing with molding from a single concrete pattern by a process which varies only in minor details, and since in the case of directions the order in

which the steps should be taken determines the order in which the directions are to be given, the making out of the general outline of the Body is a simple matter.

116. The Conclusion. — When the final step in the process is reached, the subject is finished: and since molding is only the middle part of a threefold process (pattern making, molding, and casting), the only "rounding up" the process needs at the end is the leading of the subject distinctly up to the following process — casting. Yet, since this kind of molding is only one of many, it is possible to add a Conclusion suggesting the relation of this to other kinds. That relationship might also come in the Introduction, but it would not be so effective before the reader had a clear idea of the process, and if inserted at the beginning it might lead the reader to expect a broader treatment of the subject than is to be given. The course adopted here is to limit the subject narrowly throughout the Body, giving a definite idea of molding in one simple concrete case, then in the Conclusion to "open up" the broader subject.

117. The Introduction. — The Introduction offers more troublesome problems. In the first place, the question arises whether or not *explanation* of the process should be included. It certainly would not be wise to set any one to molding by means of written directions without his first understanding the process. But it might be assumed that the reader already has knowledge of the general process of molding and the particular kind called green sand molding, in which case he would need only definite directions. If this knowledge is assumed, the paper becomes pure directions; if it is not, explanation must be given, and obviously at the start in the Introduction. This introduces into our problem the combination of explanation and directions, and since it is our purpose to study especially the complications which arise when dif-

ferent problems are more or less entangled, we shall shape the subject for readers who need the explanation.

118. If we are to make the Introduction explanatory, it will be necessary first of all to *define molding*, and so to define it as to differentiate it clearly from pattern making on the one hand and from casting on the other. If this distinction is not carefully made, the reader may tend to wander off from the subject in his imagination, and even the writer may explain points that are distinctly matters of pattern making or casting, or he may even give directions for work which is really no part of molding. Furthermore, the definition should bring out clearly the special characteristics of this kind of molding as compared with other kinds.

119. As in the case of other pieces of narrative exposition, it is necessary to decide where the *descriptive matter*, if any, should come. It happens that in molding there are many implements used, so that the problem of handling the description of implements is much more complicated than we found it in "Measuring Horizontal Angles." On the ground that we have decided that the Body should contain directions only, we should have to put all descriptions of implements in the Introduction. But if we undertook to describe all at the start, we should be in serious danger of discouraging the reader, who wants to get to the process, and we should give him so many terms and explanations which at this stage would mean little to him that he would probably forget what had been said before he found occasion to use the information. Fortunately the nature of the implements is such that the problem is simplified. Many, such as the "rammer" and the "sprue plug," are simple in shape and obvious in use. If at the point in the process where it is necessary to use the implement, the thing to be done is made clear, it is enough to mention that the act is performed with

the "rammer" or with the "sprue plug," and to refer to an illustration of the implements. In this way the description comes at the point where it is needed, yet does not enter into the text to interrupt the directions.

120. Two of the implements, the "flask" and the "sand," cannot be handled in this way, since they both need full explanation. The descriptions should not be omitted, yet if they are given after the directions are begun, they would seriously interrupt. Since these implements are the very things which give this kind of molding its special character, they belong in the Introduction as a part of the preliminary explanatory definition (118). It is a simple matter to proceed from the definition of the term "molding" to a description of the flask and of the sand before beginning the directions; and these two things are so essential to the process that if the explanation of them is properly given at the start it will not be forgotten.

121. **The outline.** — We may outline our paper, therefore, as follows: —

DIRECTIONS FOR MOLDING A SHAFT COUPLING

INTRODUCTION. (Definition.)
- *A*. Of molding as a part of foundry practice.
  - I. Distinguished from pattern making and from casting.
  - II. Illustrated in the simplest form.
- *B*. Of the process of molding a shaft coupling.
  - I. The special problem involved.
  - II. The implements necessary.
    - 1. The sand.
    - 2. The flask.

BODY. Directions for molding a shaft coupling.
- *A*, *B*, etc. (Directions, step by step.)

CONCLUSION. This process is typical of molding in general. The commonest variations are:
- *A*. Molding from a "split" pattern.
- *B*. Molding for castings which are too heavy for green sand.

122. **The synopsis.** — Filling out this outline, we get the following synopsis: —

DIRECTIONS FOR MOLDING A SHAFT COUPLING

INTRODUCTION. Molding.

A. (In general.)

I. Consists of making a hollow imprint, "mold," of an object (usually by means of a "pattern") in sand or some similar material, into which molten metal may be cast.

II. May be done by simply pressing a piece of wood into the earth of the foundry floor and removing the wood, as in molding for casting pig-iron.

B. Of a shaft coupling, such as is shown in Fig. 1, is the

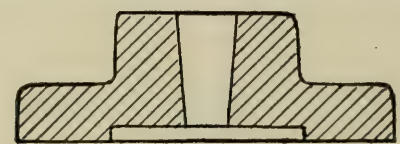


FIG. 1.

same in principle as molding for casting pig-iron, except that it requires the use of

I. Sand which

1. has such chemical properties that it will cohere properly,
2. has such physical properties that it will give a smooth surface,
3. is free from substances which when heated would injure the casting.

II. A two-part box, called a "flask" (Fig. 2), in which

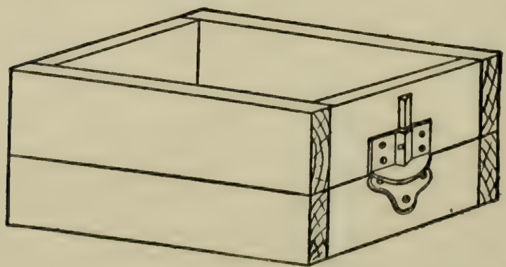


FIG. 2.

the pattern may be molded on the division line between the two parts and then removed without destroying the mold. This flask consists of

1. the upper part, called the "drag,"
2. the lower part, called the "cope,"
3. two "turnover boards" to cover top and bottom (Fig. 3),

Fig. 3.

4. guide pins on the cope and sockets in the drag so that cope and drag may be put together again, after separation, exactly as before.

Body. With sand, flask, and a few special tools to be mentioned later, molding may be done as follows: —

A. To "temper" the sand: —

I. Sprinkle the sand with water,

II. Shovel over the heap till it is evenly moistened,

III. Test the sand to see that it has the right amount of moisture. This may be done by squeezing some of the sand in the hand; if the sand retains the imprint and does not distinctly wet the hand, it is properly tempered. If the sand is too dry, it will not retain the impression of the pattern; if it is too moist, it will lead to the generation of gases when the metal is poured, which may break down the mold. Experience is necessary for proper tempering.

B. To fill the drag: —

I. Place one of the turnover boards on the bench or on something similar where it will be level and at a convenient height.

II. On this place the drag with the sockets down.

III. On the board in the center of the drag, place the

pattern (which should be clean and dry), taking pains to put the largest face down, as shown in Fig. 1.

IV. With the molder's "riddle" (Fig. 4) sift into the drag enough sand from the heap to cover

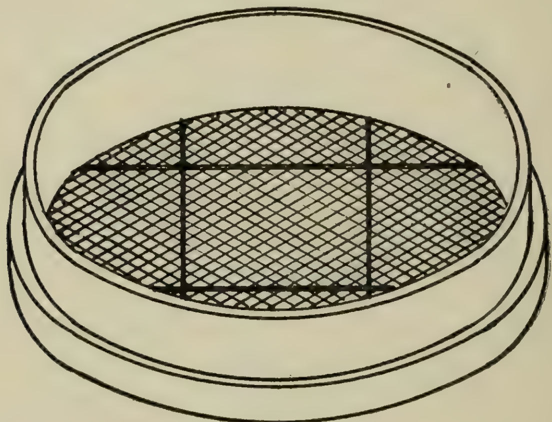


Fig. 4.

the pattern completely, that a smooth and homogeneous surface may be formed all about the pattern.

V. Shovel in from the heap enough sand to fill the drag.

VI. Ram the sand, using the butt of the "rammer" (Fig. 5) over the pattern and the wedge-shaped end, the "pein," in the corners and

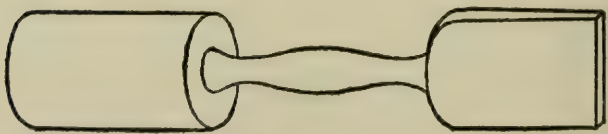


Fig. 5.

along the edges of the drag. In the center of the drag the rammer should always be pointed toward the pattern. The sand should be rammed evenly, for a spot harder than the rest is liable to make a defect, a "scab," in the casting.

VII. Level off the sand even with the top of the drag with the leveling stick (Fig. 6).

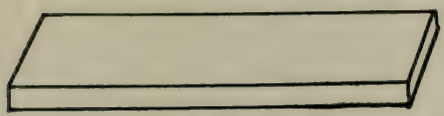


FIG. 6.

C. To finish filling the flask:

I. Put the other turnover board on top the drag.

II. Holding both the turnover boards firmly against the drag, "roll" the drag completely over, so that the pattern will be at the top.

III. Remove the top turnover board.

IV. Put on the cope so that the guide pins fit in the sockets.

V. Sprinkle some beach sand, called "parting sand," on the top of the sand in the drag, brushing off any that may fall upon the pattern. This sand is used so that the molding sand in the cope will not stick to that in the drag. It should not be left on the pattern because its chemical properties are such that it would injure the casting.

VI. Place the sprue plug (Fig. 7) upright in the sand near the pattern so that it will project above the top of the cope. This, when removed, will leave the hole through which the metal is poured.

FIG. 7.

VII. Cover the top of the pattern with riddled sand.

VIII. Fill the cope with sand shoveled from the heap, ram as before (except that extra care should be taken to ram the sand around the edges so that it will hold in the grooves of the cope when the cope is turned over), and level off.

IX. "Vent" the mold by making holes through the

sand in the cope above the pattern with a small wire, in order than any gases formed may escape.

D. To "draw" the pattern:

I. Carefully remove the cope, and set it up on one side near by, where it will not get damaged.

II. "Freeze" the edges of the mold by dropping a little water on from a sponge.

III. Drive a "drawspike" (Fig. 8) into the pattern.

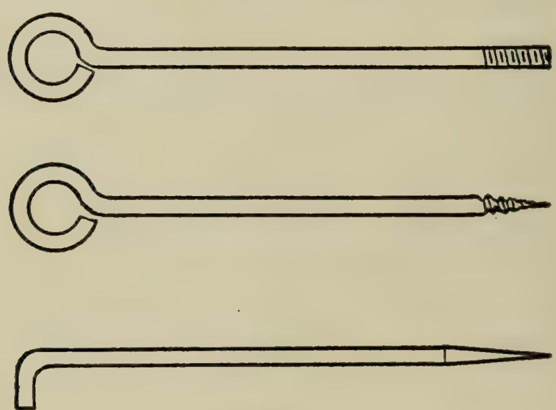


Fig. 8.

IV. Remove the pattern by tapping the drawspike gently on one side, then on another, till the pattern is loosened from the sand, and then draw out the pattern.

E. To prepare the mold for casting:

I. Cut a channel from the mold to the imprint made by the sprue plug, through which the metal is to flow,

II. Smooth over and patch up any imperfections in

Fig. 9.

the mold by means of a "slick" (Fig. 9). This requires special skill. Broken-down

places injure the casting and too much slicked-over surface lessens the necessary porousness of the sand.

III. Carefully remove the sprue plug from the cope.

IV. About the hole left by the sprue plug at the top of the cope, cut a funnel-shaped opening into which the metal may be poured.

V. Carefully replace the cope on the drag. The mold is now ready for pouring (Fig. 10).

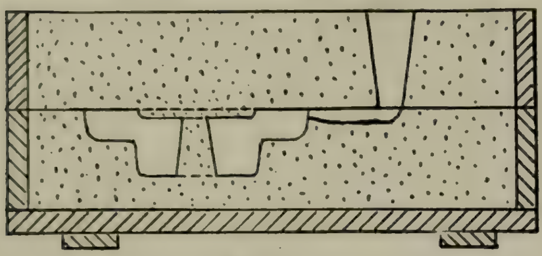


Fig. 10.

Conclusion. The process of molding a shaft coupling is typical of molding in general, but there are many different kinds of molding, each of which varies from the one given here in certain particulars. The commonest of these are those which require "split" patterns and those which require a pit for the mold.

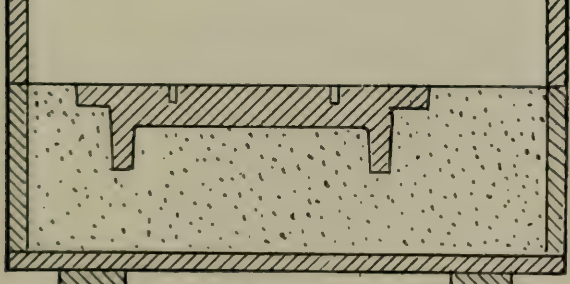


Fig. 11.

A. A split pattern is used when the object to be cast is so shaped that the pattern cannot be drawn from the sand as the pattern of the shaft coupling may be. Such a pattern is made in two parts. One part is placed in the drag at the start with the "split" surface down; the other is placed on this after the drag is turned over (Fig. 11).

B. Pit molding is used in making castings which would be too heavy for a flask. In such cases, a pit is dug in the ground and walled in.

Summary of Principles Special to Directions

123. Many of the steps in the process of molding are taken in various ways in different foundries. It is not our business to determine the best way to mold ; we are concerned only with the form of giving the directions. As a result of our study we may formulate five special principles to be observed in writing directions : (1) Directions do not necessarily include explanation, but, unless it is safe to assume that the reader already understands the general process, explanation should be added. (2) The directions should be expressed in the imperative mode, but the explanation should be given in the indicative. It is well to distinguish carefully between the two. (3) The difficulties which the reader would meet in attempting to carry out the directions must be kept in mind by the writer at every step. (4) Whenever judgment should be used in following the directions, the reader should be so informed, should be given some serviceable test, and should be told the things to be avoided. (5) When skill is required, the reader should be so informed, and should be given a definite idea of what results he is to strive for. In the following chapter another subject will be studied which includes directions.

CHAPTER VII

DESCRIPTION, NARRATION, AND DIRECTIONS COMBINED

Possibilities of combination of rhetorical forms illustrated by a study of "The Vernier," § **124**.
The general plan, §§ **125–131**.
Further details of the synopsis, §§ **132–136**.
The complete synopsis, § **137**.
Special points in "The Vernier," §§ **138–144**.
Summary of principles special to writing which combines different rhetorical forms, § **145**.

124. So far we have studied methods of explaining an instrument without telling more of its use than is necessary to make its structure clear ; and we have studied methods of explaining a process which does not involve the writer in explanation of instruments used. We have also studied methods of writing directions which call for only a little explanation at the start. In other words, we have been studying exposition which is either almost pure description, pure narration, or pure directions. But in actual writing two or three of these forms may be combined in many ways. The principles underlying such pieces of technical writing are no different from those already considered, but their application is more complicated and so needs special consideration. As an example of a subject combining the three rhetorical forms we shall take "The Vernier," to be explained to one who has no special knowledge of the instrument. The vernier itself is not difficult to understand, but in explaining it fully many details have to be given which all together make a complicated problem in logical structure.

The General Plan

125. The three main divisions. — The general character of the main divisions is easily decided on. In addition to the Body, which will give whatever explanation is necessary for one to understand the vernier and its uses, there will inevitably be a definition of the instrument, which will form the Introduction, and there may well be a Conclusion similar to that given in the paper on "Measuring Horizontal Angles in Surveying." It is of no particular value to the reader to know at the start all the kinds of implements with which verniers are used, for he has not as yet a clear idea of what a vernier is ; but at the end it may be well to "open up" the subject by explaining something of the applications of the vernier and the range of possibilities in reading minute divisions.

126. Divisions of the Body. — In order to determine the main divisions of the Body we must first decide how fully we wish to treat the subject. In textbooks this subject is generally taken up in relation to some special application of the vernier ; consequently all the facts necessary for a thorough understanding of verniers are seldom given. For such occasions a treatment which attempts to be logically complete would be out of place ; but it is our purpose in Part I to consider treatments which attempt to be more complete.

127. There are three different ways of approaching verniers. We may explain the principles of the vernier ; we may tell how to make a vernier ; or we may give directions for taking readings with a vernier. Now it is possible to explain verniers from any one of these points of view and give the reader all he needs to be told. If the principles of the vernier are adequately explained, the reader ought to be able to study out a method of making verniers or of taking readings. If directions for

reading or for making verniers are given clearly and fully, the reader ought to be able to discover the principle for himself. In the laboratory, the method is to leave the student to find out as much as possible for himself; and in writing, if brevity is the thing to be sought, we might well question the necessity of treating the subject in more than one, or at most in more than two ways. One's knowledge of anything at all complicated is never complete, effective, or insured against subsequent confusion, however, till one has seen the subject from more than a single point of view. Since there are these three phases of the subject, and since the understanding is surer the more ways a subject is studied, we shall explain the principle, the method of making, and the method of taking readings, even at the risk of having the different divisions overlap.

128. How to begin the explanation. — In explaining the principle of the vernier, the question arises, as it did in the case of "The Transit" and of "Measuring Horizontal Angles in Surveying," whether it is better to take up a simple case first and then the more difficult cases, or to carry all cases through at once. The second method is particularly tempting here, especially for one who has had much mathematical training. It is possible to give formulas for the vernier at the start, and to carry through the whole explanation in general terms applicable to all alike. To do this adequately is difficult. The results when this method is adopted in the ordinary textbook are far from satisfactory; in fact, the beginner often knows less when he has read through the explanation than he did at the start. On the other hand, if the method is skillfully carried out, it makes it possible to handle the subject more briefly and in a "neater" manner.

129. Many feel when writing under a general title that they should treat the subject in general terms; and

to those who have, through the study of mathematics, developed the faculty of reasoning in abstract terms, it usually seems better to start with abstract statements. Not so for those who have not had the advanced mathematical training. Mathematics has formulated so many carefully framed general laws, it rests so largely on the universal laws of mind, that the student, in a great part of his mathematical work and in the mathematical parts of his other scientific studies, is simply learning to apply general laws to specific cases. Consequently he comes to feel that it is natural to proceed from the abstract to the concrete. But there are mathematical habits and natural habits of thought. The natural course for the human mind to follow is from concrete cases to the abstract or general principle. Abstract principles and general cases never come first except to the specialist, and to him only rarely and in those instances where he can follow analogies which he has in fact built up elsewhere on concrete experience. The specialist may be so concerned with principles that he cares little for the concrete cases which come into direct experience; but when he is, it is generally difficult for him to express himself intelligibly except to his fellow specialists. The beginner often finds abstract explanations more meaningless or difficult to follow than he is himself ready to admit. Even the student who has acquired the habit in mathematics of proceeding from the abstract to the concrete, finds, if he attempts to read a treatise on philosophy, psychology, or any science with which he is not familiar, that it is impossible for him to get much meaning if the explanation begins with the abstract.[1] In Chapter IX we shall consider the impor-

[1] For example: "Evolution is an integration of matter and concomitant dissipation of motion; during which the matter passes from an indefinite incoherent homogeneity to a definite coherent heterogeneity;

tance of concreteness when writing for general readers; in such cases as we are studying in Part I the important thing to observe is that it is more effective to begin the explanation of a process by presenting a single concrete case which will serve as a sample of the common cases.

130. In our treatment of the vernier we are addressing the beginner, and if we explain fully one vernier, choosing the one which is simplest for the reader to understand, then gather the "laws" into such form that they will apply to any vernier, we shall reach the same form of abstract statement that we might have begun with, but at a point where it will be more serviceable. Our abstract statements will be formulated through a course of reasoning which will be fully understood at each step, and will leave with the reader the concise summary which is the thing for him to carry away as the conclusion of the whole matter.

131. **The outline.** — Our planning so far would lead us to the following outline: —

THE VERNIER

INTRODUCTION. (Definition.)
BODY.
- *A.* Explanation of the principles.
  - I. As illustrated by a simple vernier.
  - II. In form applicable to any ordinary vernier.
- *B.* The way to make a vernier to read any desired least count in connection with any scale graduation.
- *C.* Directions for taking readings with any vernier.

CONCLUSION. The application of the vernier.

and during which the retained motion undergoes a parallel transformation." This well-known formula is an example of Spencer's skill at definition, but it is not a good statement to begin an explanation of evolution with. Even Spencer does not formulate it till he has reached the end of Chapter XVII of his "First Principles."

Further Details of the Synopsis

132. In order to explain the vernier it is necessary first to *describe* it. Almost any such description should start with an illustrative figure, and all the descriptive matter that can be should thus be given. In the "legend" (191 (5)) under the figure those facts may be brought out to which attention should be directed. If the figure is satisfactory and the legend adequate, this may be enough for any one who has been trained to read drawings. For the beginner, however, it is safer to have full explanation in the text. Many of the facts needed are not given directly by the figure; they are rather inferences drawn from the facts shown. These inferences we cannot be sure the reader will draw for himself, nor can we be sure he will observe the important facts actually given unless his attention is called to them in the text. A brief but careful statement of all the facts which are necessary to a real understanding of the subject (which the experienced reader of drawings might not expect or wish to have) will lay in the beginner's mind a foundation of understanding enough more solid to warrant the extra expenditure of time and effort on the part of the writer.

133. The *explanation*, which follows the description, may be given in many different ways. A single one will be presented here. The main danger to guard against is that of telescoping the process. It is so easy for one who has mastered the subject to jump over this explanation in a single leap or two, that he forgets that the beginner who is led into doing this may fail utterly to grasp the principle, or may think he understands, only to find, when he meets a complicated case or when he is confronted by some one's careless or stupid mistatement of a case, that he is in entire confusion. The beginner needs to go over the explanation of this concrete vernier slowly and

thoroughly, in order to get a full understanding of the general laws to be stated later.

134. In the *statement of the general laws*, care should be taken to give all the laws, and to give them separately rather than in a lump, that the reader may proceed slowly and with surety. The formulas which are useful should all be given, and they should be developed in such an order and expressed in such words that the reader who does not ignore or forget what is said cannot help understanding.

135. When we come to explain *the way in which any sort of vernier may be made*, we have but to repeat facts already expressed in a slightly different form ; but the point of view is different enough to throw the facts into another light, which in itself is helpful ; furthermore, the whole may be presented briefly and will form an excellent way of clinching in summary statements the facts already given.

136. Now that we have determined upon the general outline of the whole Body, we may consider in more detail what we need to accomplish in the *Introduction*. The usual definition of the vernier explains what it is used for and, in general terms, what it is. With this general definition many would stop ; but an examination of the Body will show that there are two distinct features of the instrument which it is an advantage to distinguish clearly even at the start. There is the zero line, which corresponds to the pointer on the spring balance, for example, and marks the point on the scale the position of which is to be read ; and there are the other graduations which determine the position of the zero line when it does not coincide with a line on the scale. If the Introduction points out these two features, it brings the vernier into relation with the simpler contrivance from which it was developed (which has the pointer only) and it simplifies some of the later explanatory matter.

The Complete Synopsis

137. We may now proceed to make a complete synopsis, as follows : —

THE VERNIER

INTRODUCTION. (Definition.) The vernier:

A. Is a device for measuring parts of a straight or circular scale smaller than it would be practical to read if graduated on the scale itself.

B. Consists of a short auxiliary scale (Fig. 1), moving along the main scale, with equal divisions numbered 0, 1, 2, 3, etc., of which

I. one, the "zero line of the vernier,"

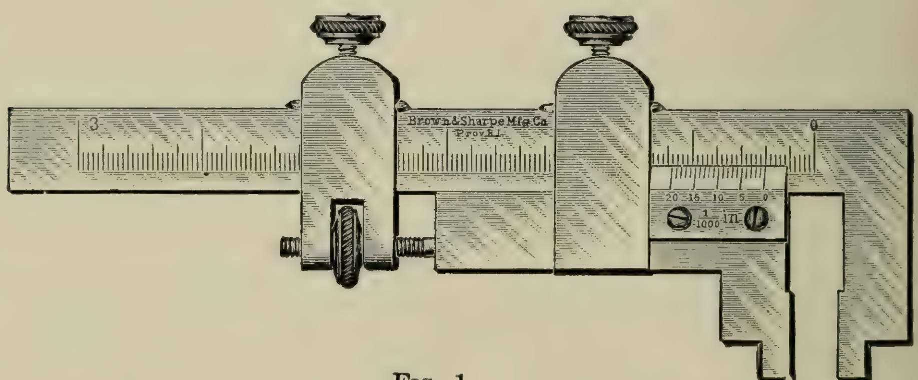


FIG. 1.

1. serves to indicate on the main scale the position of a point the distance of which from a fixed point, usually the zero of the main scale, is desired, and
2. corresponds to the pointer on the scale of a spring balance or similar instrument;

II. the others

1. serve to measure the distance of the zero line from the nearest scale line in the direction of the scale zero, when the vernier zero is between two scale lines (which "fractional part" must be estimated by the eye or ignored when there is only a pointer),
2. and thus form the essential part of the vernier.

BODY. (Principles of the vernier, directions for making and for taking readings.)

A. Explanation of the principles.

I. As illustrated by a simple decimal vernier (Fig. 2).

1. Description of the figure.

a. Main scale (*S*), divided into inches and tenths,

b. vernier (*V*), graduated into 10 equal parts, the division lines numbered from 0 to 10, the 0 line serving as the pointer,

c. the 10 vernier divisions exactly equal in length to 9 scale divisions ($10\,v = 9\,s$),

d. therefore each vernier space equal in length to $\frac{9}{10}$ of a scale space, or $\frac{1}{10}$ of a scale space less than a scale space ($v = \frac{9}{10}\,s$) ($v = s - \frac{1}{10}\,s$),

e. vernier 0 and vernier 10 exactly coincide with lines on the scale; no other line does.

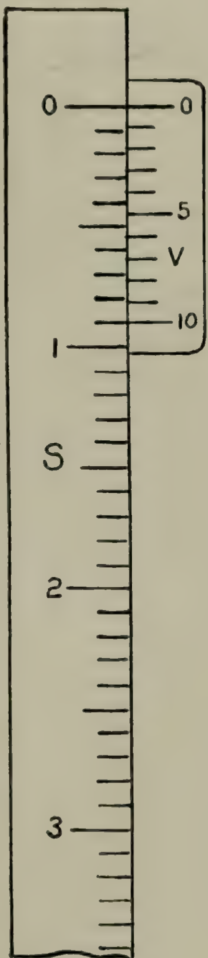


FIG. 2.

2. Explanation of the fundamental principle.

a. Since a space on the vernier is $\frac{1}{10}$ of a scale space shorter than a scale space, when the vernier 0 coincides with a line on the scale, vernier 1 must fall short of the next scale line $\frac{1}{10}$ of a scale space; vernier 2 must fall short of the next following scale line twice as much, $\frac{2}{10}$; vernier 3 must fall short $\frac{3}{10}$, and so on- In other words, when the vernier 0 coin. cides with a line on the scale, each vernier line falls short of coincidence with

the corresponding scale line as many tenths as the number of the vernier line.

b. Conversely, if the vernier 0 is moved forward from coincidence toward the next scale line 1, 2, 3, or any number of tenths, the vernier line of the same number as the number of tenths moved will always be brought into coincidence.

c. Hence when the vernier 0 has been moved forward from a line on the main scale an unknown distance toward the next scale line, that distance may be determined to the nearest tenth by observing the number of the coinciding vernier line. If no line exactly coincides, the reading must be estimated between that given by the vernier line which falls short of coincidence the least distance and the following vernier line which will fall slightly beyond coincidence.

d. For example, in Fig. 3, the vernier 0 has been moved so that it stands between 1.3 and 1.4 on the scale; vernier 6 exactly coincides with a line on the main scale; therefore we know that vernier 0 is $\frac{6}{10}$ of a scale space beyond 1.3. Since in this case a scale space is $\frac{1}{10}$ of an inch, $\frac{1}{10}$ of $\frac{6}{10}$ in. is $\frac{6}{100}$ in., therefore the total reading is $1.3 + .06 = 1.36$ in.

e. The vernier reading may be verified in the following way: when the vernier 6 is in coincidence, vernier 5 must have passed beyond the next preceding scale line $\frac{1}{10}$, vernier 4 must have passed $\frac{2}{10}$ beyond the corresponding scale line, vernier 3, $\frac{3}{10}$, vernier 2, $\frac{4}{10}$, vernier 1, $\frac{5}{10}$, and vernier 0, $\frac{6}{10}$.

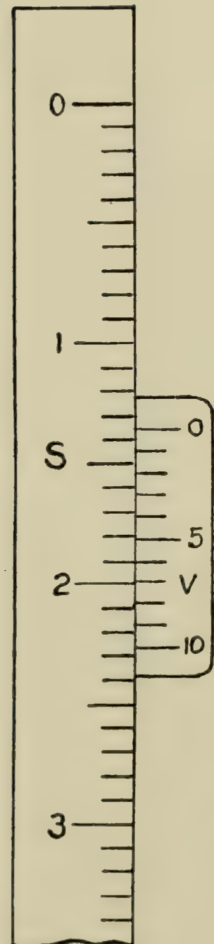


FIG. 3.

II. In form applicable to any ordinary vernier.

1. General laws.

a. The shortest space which can be measured by a vernier is called its "least count" (l. c.).

b. The least count is a fractional part of the shortest space on the main scale,

y. the numerator of which is 1,

z. the denominator, any whole number (n), but in practice such a number as will make a convenient fraction: 10 or a multiple of 10 for a decimal scale; 60 or a factor of 60 (in some cases 120) for a vernier on a graduated circle or arc $\left(\text{l. c.} = \frac{1}{n}s \text{ or } \frac{s}{n}\right)$.

c. The spaces on the vernier and the spaces on the main scale must differ in length by the amount of the least count.

d. The number of graduations on the vernier must be such that when the vernier zero is in coincidence, the increasing distance of the succeeding vernier lines from the corresponding scale lines will bring the last vernier line also into coincidence. Since the difference in length between a vernier space and a scale is $\frac{1}{n}s$, there must be n divisions on the vernier.

e. The n vernier divisions and the number of scale divisions which exactly equal in length n vernier divisions will differ by 1, but the n vernier divisions may be equal in length to either $n - 1$ or $n + 1$ scale divisions ($nv = n \pm 1\,s$).

f. It should be noted that for a given graduated scale and a given least count the length of s and the value of n are invariable, but that the number of scale divisions equal to n vernier divisions, and the length of the vernier division may vary.

2. Special forms of verniers.

a. "Direct" verniers are those in which $nv = (n - 1)\,s$. They are the commonest and are similar to the one already explained (Fig. 2).

b. "Retrograde" verniers are those in which $nv = (n + 1)s$. They are similar to the direct verniers except that the numbers on the vernier instead of increasing in the same directions as those on the main scale, should increase in the opposite direction. The lines are numbered in this direction because, the vernier spaces being longer than the scale spaces instead of shorter as in the direct, the vernier lines approach coincidence in the opposite direction, as shown in Fig. 4.

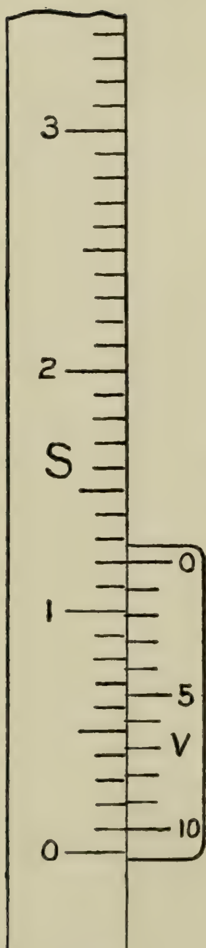


Fig. 4.

c. "Indirect" verniers are those graduated like the retrograde, but with the lines numbered in the same direction as those on the main scale, as in the case of the direct. They are called "indirect" because they give the distance of the vernier zero from the scale line next *farther* from the scale zero, so that in order to get the real reading it is necessary to subtract the fractional reading given by the coinciding line from a whole scale space, as will be seen in Fig. 5. If, for example, the number of the coinciding line is 3, the reading is $\frac{7}{10}$. These verniers are not in practical use now.

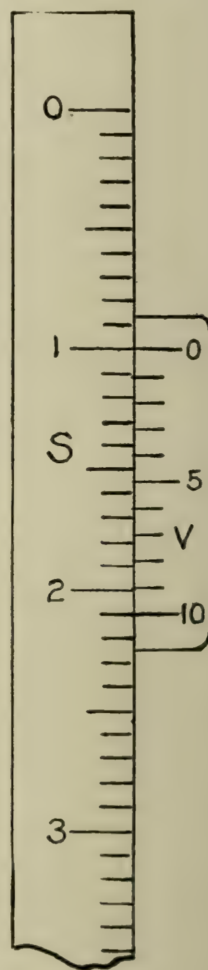


Fig. 5.

d. "Double" verniers are those which are graduated on both sides of the vernier zero. This is the regular form on such instruments as the transit where it is

FIG. 6.

necessary to take readings in either direction on the limb (Fig. 6).

e. "Double-half" verniers are those which are graduated on both sides of the zero but to only one half the number (n) each way. In this case two sets of numbers are marked on each side as shown in Fig. 7, the numerically higher numbers on each side serving as the con-

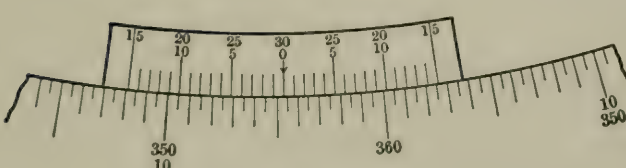


FIG. 7.

tinuance of the lower series on the other side. It is possible to take readings with such half verniers because the two extreme lines of the vernier, being n spaces apart, must always stand at the same distance from coincidence, so that if a coinciding line is not found between the vernier zero and the last vernier mark in the direction the read-

ing is taken, it is only necessary to turn to the opposite end of the vernier and look from there toward the vernier zero.

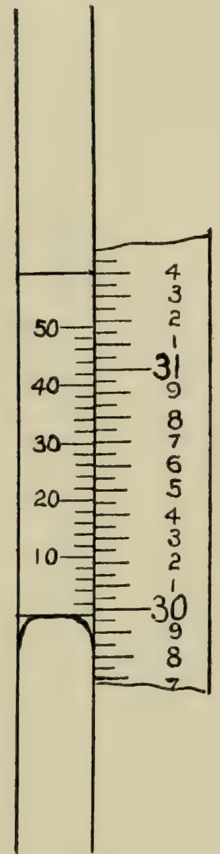


FIG. 8.

f. "Single-half" verniers are sometimes used on sextants and barometers (Fig. 8). In order to take readings with such a vernier, each of the scale divisions which differ from the vernier divisions by the length of the least count must themselves be divided into halves. If the least count is $\frac{1}{120}$, such a vernier would have but 60 spaces. Readings from $\frac{1}{120}$ to $\frac{59}{120}$ are taken in the usual way by noting the number of the vernier line coinciding with a scale line; a reading of $\frac{60}{120}$ is given by the main scale, the vernier zero standing in coincidence with a half division line on the scale; readings from $\frac{61}{120}$ to $\frac{119}{120}$ are found as $\frac{1}{120}$, etc., to be added to $\frac{60}{120}$ given by the half division line which is in this case the line which gives the scale reading. N.B. The term "scale space" should always be used for that space which differs from a vernier space by the length of the least count. Half such a space should be called a "half scale space."

B. To make a vernier to read any desired least count in connection with any scale graduation, it is necessary:

I. To decide upon the value of n in the fraction $\frac{s}{n}$ which will give the desired least count.

II. To mark off a total length for the vernier scale equal to $n - 1$ if a direct vernier is desired, or $n + 1$ if a retrograde or an indirect vernier is desired (twice $n - 1$ for a double vernier or one half $n - 1$ for a half vernier).

III. To divide this total length into n equal part (twice n for a double vernier or one half n for a half vernier).

IV. To mark the zero line:
   1. at the end nearest the zero of the main scale for a direct vernier (whole or single half), or for an indirect,
   2. at the end farthest from the main scale zero for a retrograde,
   3. on the center line for a double (whole or half) vernier.

V. To number the other lines from the vernier zero in any way that will make it easy to identify them, remembering to double number the lines on each side the zero in the "double-half" vernier.

IV. To mark half space lines on the main scale in case a single half vernier is used.

C. Directions for taking readings with any vernier.

I. Examine the vernier to determine its least count (sn), by observing
   1. the value of the shortest scale division (s),
   2. the number of divisions (n) of the whole vernier. If there is any doubt as to what length constitutes the whole vernier, it may be decided by setting the vernier zero in coincidence and noting that
      a. if the extreme line also coincides with a scale division line the distance between the zero and that line is the whole vernier,
      b. if the extreme line falls halfway between two scale lines or on a scale half division line, the distance between the zero and that vernier line is a half vernier.

II. Take the reading by
   1. noting the "whole number," that is to say, the value of the scale division last passed by the vernier zero as it has moved from the scale zero,
   2. reading the "fractional part," if any, that is, the fractional part of a scale division which the vernier zero has passed beyond the scale line giving the whole number. This is done by multiplying

the least count by the number of the coinciding vernier line,

3. adding the "fractional part" to the "whole number" for the reading required.

III. For example, in Fig. 9:

1. $s = \frac{1}{20}$ in.
$n = 25.$
least count, $\frac{s}{n} = \frac{1}{500}$ in.

2. The whole number = 29.20,

3. the fractional part = least count × no. of coinciding line,
$\frac{1}{500} \times 6 = \frac{6}{500}$ or .012.

4. the required reading = 29.212 inches.

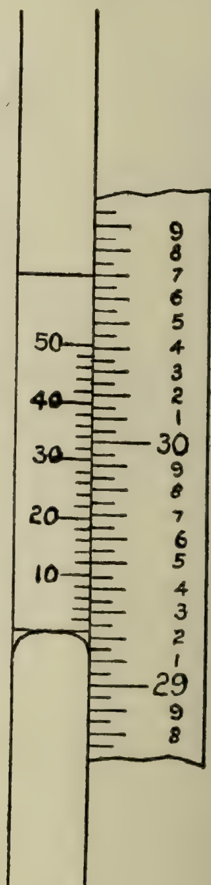


Fig. 9.

Conclusion. (Application and precision.) Verniers:

A. Are used in connection with

I. straight scales on such instruments as calipers, beam compasses, mercury barometers, and target rods,

II. limbs on such instruments as transits, protractors, spectrometers, aneroid barometers, and sextants.

B. Commonly read from $\frac{1}{10}$ to $\frac{1}{120}$ of a scale space, and have least counts as fine as $\frac{1}{2500}$ of an inch, or $\frac{1}{1000}$ mm.

Special Points in "The Vernier"

138. In the *definition* of the vernier there is one point which has not yet been touched on which needs a word. It is common to say simply that the vernier is for reading "fractional parts," but the addition of the words, "smaller than it would be practical to read if they were graduated on the scale itself," brings before the reader the fact that the determination of the point where it

is well to stop graduating the main scale and resort to the vernier is not a theoretical, but a practical question. It would be possible to graduate a main scale as minutely as a vernier would read, but to distinguish the graduations would require a powerful compound microscope, so that such graduations would not be at all practical. It is not usual to graduate a stadia pole finer than tenths of a foot on account of the distance at which readings are made, but we may add a vernier, if desired, to read to hundredths of a foot. On the limb of a transit, on the other hand, for ordinary land surveying the graduations may be equal to thirds of a degree with a vernier reading fortieths (least count = ½ minute); and on transits for more precise work the limb may give sixths of a degree and the vernier read sixtieths (least count 10 seconds). In short the relationship of the vernier to the scale is a practical question to be determined in each specific case.

139. In the *description of Fig.* 2 (Body A. I. 1) *a*, *b*, *c*, and the first part of *e* simply state facts shown in the figure; *d* and the second part of *e* draw obvious inferences (**132**). Divisions *a* and *b* might be omitted in an actual paper on the vernier, since the facts are clearly indicated in the figure, and whatever of them is essential for an understanding of the explanation is brought out in *c*, *d*, and *e*. If the remaining descriptive facts are stated, it is not because the reader is assumed not to be able to discover them, but because we have thus before us, whether the reader happens to be looking for them or not, the actual facts upon which the following explanation rests. More than this, a simple brief statement of these facts enables us to insert three useful formulas in the concrete form applicable to this specific case, and to emphasize the fact (about which confusion most frequently arises) that the difference between length of the vernier division and the length of the scale division is a fraction of a scale division, not of a vernier division.

140. Of the various ways in which the *explanation of the fundamental principles* (Body A. I. 2) may be given, the one here was chosen because it seems the best to forestall the various difficulties the beginner is in danger of falling into. This explanation may be shortened, and generally is at two points. In the first place, the distance that a line on the vernier falls short of coincidence when vernier zero is in coincidence is often deduced from the statement about a single line or at most two lines. The general objection to condensing such an explanation, namely, that it is dangerous even to seem to draw a universal conclusion from one

or two cases, does not hold here where we are dealing with such a simple mathematical fact; but the beginner, who has not yet comprehended the principle, may not have in mind the true relationship and may try to find in the numbers 1 and 2, if they alone are mentioned, some clew to the principle. In the second place, of the statements made under *a*, *b*, *c*, and *d*, any one or even two may be omitted; yet each is helpful. The first, *a*, joins the explanation closely to the vernier as drawn and described; *b* shows what effect is produced on the relative positions of the lines when the vernier zero is moved from coincidence with one line toward coincidence with the next; *c* draws the conclusion which we are after, that is to say, the fact on which we determine the position of the vernier when it has moved an unknown distance from coincidence. The statements under *d* and *e* are not logically necessary, but after the principles are established, the application to an illustrative case and the proof of the deduction, getting at the principles from a different point of view, serve to clinch the explanation so that ordinary intelligence and attention will not miss it.

141. In the statement of the *general laws*, care has been taken (**134**) to include all the laws and to give them separately rather than in a lump. Any one who has never undertaken to get statements of general laws such as these from the untrained would be astonished to find how many points may be overlooked or misstated.

142. The *special forms of verniers* are usually not so fully treated; and since the "direct" and the "retrograde" only are in use on modern instruments, the "indirect" might well be omitted and the rest left for the reader to study out for himself. Here, however, it is the object to treat the subject fully and so each form is included because each adds some light and makes it more certain that the reader will get a thorough understanding.

143. The *explanation of the way to make any desired vernier* again is something seldom given. All the information needed for making verniers is, as we have seen (**135**), to be inferred from the preceding explanations, and if the object were to make the reader learn all he could from his personal investigations and reasonings, it certainly would be better to leave him to solve any problem of making a vernier. For the purpose of giving the reader a thorough mastery of the subject, this brief explanation summing up the facts in a new way is worth while.

144. In general it may be said that a treatment of "The Vernier" as full as has been given here would be ineffective because of its length. For practical purposes it would need to be cut. In shortening, the forms of the vernier not in common use should be left out first, then the cases which the reader ought to be able to work out for himself, and lastly the most obvious of the logical steps.

Summary of Principles Special to Writing which combines Different Rhetorical Forms

145. In complicated pieces of technical writing many special problems arise, each of which has to be solved on its own merits ; but a careful study of a single subject such as " The Vernier " will throw light on almost any problem which may be met. The general structure is no different in writing which combines different rhetorical forms from what it is in the simpler forms, nor are the principles of description, narration, or directions any different. The new problems all arise in combining the forms. If one form is simply subsidiary to that which makes up the main part of the paper, we have a case like that of "The Transit," which briefly explains the method of using in order to make the structure clear, or like "Measuring Horizontal Angles," which describes the marking of the angle in order to give the explanation of the process concretely, or like "Directions for Molding a Shaft Coupling," which describes the flask and briefly explains other processes of molding in order that the directions may be given more effectively. We have new problems when different rhetorical forms are combined, each of which is equally essential. For such cases we may lay down the following general principles: (1) That form should come first which is simplest for the reader to grasp. (2) That form should come first which gives the broadest grasp of the subject, or which goes most directly to the essence of the matter as the reader needs to get it at the start. (3) Those

forms should come later which are more difficult to grasp and are most benefited by being preceded by simpler explanation. (4) If the various forms are not logically necessary but are inserted to build up a more thorough understanding on the part of the reader, care should be taken not to insert the same facts twice. What may be logically repetition, should be so expressed that every fact is presented on the different occasions in distinctly different relations. (5) If, as generally is the case, it is desirable not to give an entirely complete treatment, the parts to be excluded should be carefully determined on the basis of the actual needs of the reader.

PART II

PRACTICAL APPLICATION OF PRINCIPLES

CHAPTER VIII

THE ESSENTIALS OF LOGICAL STRUCTURE

Theory and practice in technical writing, §§ **146–151**.
Importance of logical structure, §§ **152–154**.
The general structure, §§ **155, 156**.
Introduction, Conclusion, and Title, §§ **157–171**.
Special problems of the different rhetorical forms, §§ **174–177**.
Means of giving extra help to the reader, §§ **178–183**.
The bearings of these suggestions, § **184**.

Theory and Practice in Technical Writing

146. **Part I and Part II.** — In Part I we have been considering what determines, or should determine, the structure of any piece of technical writing. We have formulated principles in general terms and have applied them in writing synopses of subjects chosen as types of the different rhetorical forms of exposition. Our study so far has been theoretical, and the work which should be done in connection with these earlier chapters is of the nature of general logical drill. In Part II we shall consider the application of principles in practice.

147. **Relation of theory and practice.** — The study of principles alone never produced a powerful sermon, a masterly argument, a successful drama, or a beautiful poem; no more can it be expected to give the engineer the ability to express his ideas in the most effective way. The native powers of the writer are sure to count for or against, and even in turning those powers towards success (as may be done by study) theory alone will not evolve the best expression. The engineer, like writers in other

fields, needs, in order to get the best help, to turn to the works of the most efficient writers in his special field. Each science, each profession, has its own language, its own style of expression, its own habits of presentation ; if any one is to write on subjects belonging to a given profession, he must use the language and take due account of the actual habits of that profession.

148. Technical writing is peculiar, however, in that it has not been studied as exhaustively as the other forms. When the dramatist, the lawyer, or the poet undertakes to give expression to his ideas, he realizes how much his success depends on the skill with which he can put his ideas into words ; he has studied masterpieces in his special form and, with the possibilities clearly in mind, labors in writing as at a work of art. The engineer, on the other hand, is most impressed by the need of a writer's having himself a thorough understanding of his subject. Almost always he thinks too exclusively of the facts and consequently does not convey them effectively to others. Even if he realizes the value of careful expression, few of the writings with which he is familiar set up high standards to inspire him. In engineering reports, textbooks, and magazine articles, we find crudeness in the structure of sentences and of paragraphs and ineffectiveness of general structure, such as we do not find in the writings of equally intelligent members of other professions.[1] For this reason and because exposition is, more than any other

[1] As an example of the way in which needless difficulties may be heaped on a reader, even in expressing a simple fact, Article III of the Appendix may be cited. It is easy and amusing to collect examples of faulty composition, but such a collection in a textbook is not helpful. It would be of little value to illustrate here ways not to write. Any one who is striving to improve his own style, however, does well to note in his own writing and in his reading cases of ineffective expression and to discover, if he can, exactly what the trouble is and how the ideas might have been expressed better.

form, a matter of logical presentation, the engineer would profit by making himself familiar with fundamental principles. This will not take the place of a study of actual practice, from which alone a good technical style can be developed, but it enables one in writing and in reading to make careful logical discriminations.

149. **This chapter.** — The conclusions which the theoretical study of Part I leads to will be summed up in this chapter in the form of practical suggestions. Each point will be accompanied by a reference to the sections in the earlier chapters in which the appropriate principle is discussed; but the main purpose of the chapter is to give practical illustrations of the suggestions by reference to one or more of the articles in the Appendix.

150. In consequence of this arrangement any engineer who has not the time for logical drill and who does not care for the theoretical study will find it entirely possible to begin his study of technical writing with this chapter (11). If the suggestions given do not justify themselves to his mind, he may at any time get the benefit of fuller discussion and illustration of the principle involved by looking up the reference to the earlier sections. Should his interest in the theoretical study in that way be aroused, he will then turn to Part I with a clearer perception of its value.

151. In actual writing there are many kinds of practical problems. So far we have not considered one of the most important and most difficult, that of fitting what we write to the knowledge and to the needs of the readers we are addressing. We shall leave this subject for the following chapters entitled "Addressing General Readers" and "Addressing Specialists." Nor have we yet considered the form of the final writing, which offers many problems of its own, or the methods by which a writer can effectively and economically gather together and "compose" his

ideas. These subjects will be discussed in Chapters XI and XII. Even in our attempt to make practical applications we shall, in this chapter, still limit ourselves to the consideration of those problems on which our theoretical study has thrown light, that is to say, the general problems of structure.

Importance of Logical Structure

152. Logicalness of form is not the only ideal to be striven for in technical writing, as we shall see in the remaining chapters. But the inability of the writer to think straight or the difficulty he finds in giving his ideas proper expression should not lead him to flatter himself that there are any other qualities which make logical structure unnecessary. If the engineer gives serious thought to what he writes, he is sure to find places where the structure might be improved ; but he realizes that the improvement of even minor points requires much time and effort and he may not think it worth the cost. In his reading he finds books which are well written and books which are not.[1]

[1] "Of books there have always been many kinds, good books and bad books, books which were good literature and bad morals, and books whose morals were like Cæsar's wife, beyond reproach, which were nevertheless bad literature. So, to-day, there are books which are good literature but bad technology, and books which are good technology but bad from a literary standpoint. The former are largely a product of 'hack' technology writers, and the latter are often, we are sorry to say, produced by good practical chemists and engineers. It has in some cases been a fact that good books on chemical technology were the product of men who knew comparatively little of the practice of the subject about which they wrote. These writers were men, however, of excellent breadth of mind, who had at their command a large amount of technical literature, and who were constituted with a judicial sense for weighing the literary productions of others, selecting the good from the bad in this, and placing the former before the reader in an evenly balanced and smoothly reading treatise. Such books contribute nothing to the world's store of technical knowledge, but nevertheless constitute welcome additions to our technical libraries. Other books have been prepared by men of large experience in technology, yet they are seldom consulted and

Often he has had to study over a passage to get what finally proved to be simple meaning, or he has been unable to make out exactly what was intended. Often he has found himself forced to follow what he was sure was not a natural course. But he has accepted these trials and distresses as inevitable, or his mind has gradually hardened itself to such exercise till he feels no sense of weariness, no realization that he is going through needless labor. So farmers have bumped over roads that are little better than pasture lanes all their lives without ever seriously considering that roads might and should be built so as to make transportation more comfortable and more economical. In writing, the real length of the subject and the burdens it puts upon the reader because of the inherent difficulties of the subject matter cannot be reduced, any more than the length of the road to market or the weight of the load can be reduecd ; but the expression, like the surface of the road, may be made smooth and easy.

153. For most writers it is a slow and laborious process to give any complicated piece of technical writing, or even a piece that seems simple, effective structure ; but it should be easy for the engineer to appreciate how uneconomical it is to make it unnecessarily difficult for a reader to get the meaning. There is as great a difference between a piece of exposition poorly written and one well

would be even less so were they written by men not so distinguished as their authors. The reason for this is that the writers disregard all rules for technical writing and present their materials in a crude illogical way. Unquestionably the best book could be written by the man who knows the subject best. It is seldom a case of grammar or rhetoric, and not often a case of lack of facility in expressing themselves that makes books by these men failures. It is usually the neglect to look before they leap and to familiarize themselves with books before they write, as they would with a machine or process before installing it in their plants." — "The Making of a Technical Book," Richard K. Meade, editor of *The Chemical Engineer*. From *The Chemical Engineer*, December, 1908.

written as there is between a plant poorly managed and one well managed, or between a mill building poorly designed and one well designed. Everywhere efficient work demands much more ability, patience, and devotion to high ideals than poor work ; but it is worth the price. Just as the extra time and effort required by the manager of a plant or by the designer of a mill to do his work well is paid for many times over by all those employed in that plant or mill, so the extra care that a writer needs to devote in order to perfect the form in which he presents his ideas is paid for in time and effort saved for every reader of what he has written. As engineers are better trained and as they come to recognize more clearly that the sharing of their ideas with others is a most important part of their work, they will as writers produce, and as readers demand, a form of expression which will compare favorably with the masterpieces of other forms of composition.

154. **The value of synopses.** — In the earlier chapters we built up logical structures entirely in the form of synopses (Chapter II and Chapter III, 40). The question naturally arises, Do practical writers ever make use of this form? Rather the question should be, Is it ever worth while for the busy practical man to take the time to write a synopsis? Since we are not to concern ourselves about methods of writing till we reach Chapter XII, we cannot attempt to answer the question here. All we need to do at present is to emphasize again the fact that the best means of criticizing structure, of detecting wherein a piece of exposition is not accurate, complete, logical, or economically presented, and of discovering how it may be improved, is the synopsis (29). If the engineer can criticize what he reads and especially what he writes thoroughly and accurately in the full final form, all well and good ; if he cannot, and few can, he will find the best means of assistance in the synopsis.

The General Structure

155. The untrained writer is often overwhelmed, in dealing with a complicated subject, by the multiplicity of the problems which arise when he attempts to plan his work or to revise the first rough draft. In his uncertainty as to where and how to begin, what he probably desires is not so much theory as some simple practical tests or rules which will show him at once his shortcomings and their remedies. Experience has shown that if the writer will test his production to see if it is in accord with four rules (which may be readily applied to the synopsis form), he will be able to detect all important defects of structure.

1. *The facts should be presented in an order which is logical for the reader* (**35**, **48–51**). What order is logical for the reader has to be determined in each case. In Article I, the parts of the transit are taken up from the top of the instrument to the bottom and from the center of the instrument out. This order is easy to follow in the illustration of the instrument; it begins with the part which it is natural to think of first, that which gives the line of sight; and makes it possible to indicate the working of the various parts without the necessity of doubling on the general course of describing the parts. In a similar way, Article V explains first the part of the wet machine in which the pulp is received and follows the course of the pulp through the machine to the part from which the sheets are taken. In Article XI the process of color photography is explained in the order in which the steps are actually taken. In Article VII the directions for interpolating are given according to the order the student should follow. In general, we have found that the general conception should be given before the details (**52–54**) (Articles I, XVII, and XXIV); that the simple should come before the complex (**103**) (Articles I, VII, and XXIV); and that the concrete should come before the abstract (**87**, **128**) (Article VII).
2. *The structure should be divided, first, into main divisions* (**55–66**), *then into such minor divisions as will bring out fully all important relations of the separate facts* (**64–66**).

3. *All the parts of each division should be, in fact, strictly coördinate* (**42**).
4. *The sum of all the parts of each division should equal the whole of that division, no more and no less* (**43**).

156. These rules do not hold strictly in all cases. The general order of development may at times be broken up because it is more natural or more helpful to bring in certain of the facts out of that order. For example, in Article I, after the parts of the transit from the telescope to the tripod have been explained, the writer takes up the clamp screws and the tangent screws because he wishes to group together the attachments for operating the two motions. Divisions which logic would call for may be omitted to avoid an excessively complicated system of division. Facts may at times be repeated in order to emphasize them, and other facts which logic demands may be omitted because they are too obvious to need mention or because they are of so little importance that they may be ignored. But no deviation from these rules should be countenanced which is brought about simply because of lack of consideration on the part of the writer. Where these rules should be applied rigidly and where slight deviations are possible may be best seen by analyzing technical articles and deciding in each case where deviation is found, whether or not the author was justified.

Introduction, Conclusion, and Title

157. In addition to the main division which we call the Body, which should contain the whole mass of information which it is the essential purpose of the writer to convey, there are two other main divisions possible, the Introduction and the Conclusion. These two divisions and the Title should receive special consideration to see that they properly perform their functions in the general structure.

158. **Introduction.** — It is the business of the Introduction (56–59) to lay a solid foundation on which the reasoning of the Body may be securely built. In other words, the Introduction should start with knowledge and interest which it is safe to assume the reader has (Articles XI, XIII, XVI), and, by recalling reshaping and developing them, prepare his mind to grasp intelligently the subject matter which the Body is to present. How much knowledge and what interest it is safe to assume on the part of the reader, it is often difficult to decide. In all cases, however, the reader must have some definite knowledge on which the writer may rest his explanation or it is impossible to explain. If we are to explain an electric motor, we must be assured that the reader knows something at least about the action of a magnetic needle and of a horseshoe magnet, and that he has observed the use of wires for transmitting electricity. If not, we may explain such things to him, but not as yet a motor. On the knowledge which the reader has, the Introduction must rest ; and it is of great importance that this knowledge be carefully shaped in any way it needs to be in order to prepare the reader for the explanation to follow.

159. Some articles are addressed to those only who have such knowledge and interest that they need little if any introductory explanation. Article IV, for example, is taken from a descriptive catalogue of machine tools ; the readers can safely be assumed to have a practical knowledge of machine tools and to be interested in different makes ; the fact that this article is in the catalogue of a definite concern explains its nature; and the Title limits it to a definite machine. In such cases no Introduction is necessary, save that given by the Title. In other cases long and elaborate Introductions are either necessary or helpful. Article V is not addressed to those thoroughly familiar with the manufacture of pulp, con-

sequently a detailed explanation of the wet machine would have little meaning to them till they had in mind the foundational understanding of the process of pulp manufacture. The various articles in the Appendix illustrate Introductions of different degrees of elaborateness.

160. The main purpose of the Introduction is to define the subject in terms which are intelligible to the reader in order that he may understand just what the Body is to explain. Almost any object or process may be defined in many ways. An elm tree, for example, would be defined in one way by an artist, in another by a lumberman, in another by a landscape architect, and in still another by a city engineer. The writer does not have to consider all possibilities, he has simply to define in such a way as to give his reader the conception needed to understand the following Body. Article I defines the transit by naming the operations for which it is used. Article IV defines turret head power bolt cutters simply by differentiating them from other machine tools by the Title. Article V defines the wet machine by explaining the process of manufacturing wood pulp and indicating at what point in the process the wet machine is used. Article XV defines the new separator for the removal of slate from coal by explaining the objects sought in designing the separator. The dictionary undertakes to give general explanation of terms so it will be clear what each stands for in its various uses; the Introduction to a piece of exposition should define the subject so that the reader will understand exactly what is to be treated in this particular case.

161. The definition may determine the bounds of the subject, it may differentiate the subject from others with which the reader may confuse it, or it may give the sum total of the parts of which it is made up. When the definition determines the bounds, it may take the course of

narrowing the subject, as in Article XI, where the Title is "Color Photography," but the Introduction limits the subject to the Lumière system ; or it may broaden the subject, as in Article VI, where the title " Potable Water " and the first sentence would lead the reader to think that the subject was limited to drinking water, but the last sentence of the first paragraph broadens it to include " the whole water supply of a city or town." When the definition differentiates the subject from others, it may do it in an elaborate way, as in Article V, where the relation of the wet machine to the others used in pulp manufacture is fully indicated ; it may do it by brief statement, as in Article II or Article XVIII, or by implication, as in Article I. When the definition gives the list of the parts which make up the subject, the " parts " may be named, as in Article XIX ; or merely suggested, as in Article I (where the " parts " of the subject are the " plain " transit, explained in the selection given in the Appendix, and the " complete " transit, explained in sections following in the book from which this article is taken); or they may be more formally stated, as in Article VI. When the parts of the subject are thus summed up in the Introduction, they should suggest or formally explain the general plan of treatment to be followed in the Body (74, 97).

162. Often the definition of the subject of the piece of exposition makes necessary the definition of other terms. In Article VII the definition of "interpolation" entails the use of five technical terms, each of which is defined: " table," " argument," and " function " by illustration ; and "tabular intervals" and "tabular differences" by verbal explanation. Where the Introduction thus becomes a series of definitions building up the desired conception, it is sometimes best to give the general definition first and then the definitions of the involved terms (as

in Article VII or Article XVIII); sometimes it is better to lead up to an explanation of the actual subject through definition of terms on which the understanding of the subject depend (as in Article XII). In certain cases it is impossible (as in Article XII) or at least difficult (as in Article V) for the reader to understand any definition of the subject till the ground is cleared by the definition of other terms; but where possible, the Introduction of such preliminary definitions should be avoided because there is danger of confusing the reader as to what the subject is or of making the start seem unnecessarily slow.

163. Sometimes in order to give the reader the desired conception of the subject, it is advisable to impress on him its importance. This may be done by implication (as in Article VI) or by more explicit statement (as in Articles VIII and XVI). In other cases the value of the treatment may depend largely on the right of the author to speak with authority. He cannot put a just valuation on himself, but he may state frankly and accurately his experience and any facts which warrant his writing on the subject (Article IX).

164. The Introduction is not a part of the explanation which it is the main purpose of the writer to give the reader; it should not contain facts which belong to that explanation, and it should be so presented that the reader will feel that in it he is getting but preliminary explanation. If the Introduction is anything more than a simple definition expressed in a sentence or short paragraph, it should be clearly marked off from the Body. This should be done, not only because it will save the reader from possible confusion, but because it will help the writer to limit himself in the Introduction to just those facts necessary for introductory purposes. In such a case as that of Article V, for example, the writer might easily run off into ex-

planations of the process of wood pulp manufacture which would not be needed to make clear the purpose the wet machine serves, if he did not mark off that part of his paper as Introduction. It is possible for the change from Introduction to Body to be made gradually with no distinct point of division indicated (as in Article XII); but under ordinary circumstances it is wiser to indicate clearly the division. This may be done by simply rounding the Introduction back to the Title (as in Article V) or by formally explaining that at this point the Introduction ends and the Body begins (as in Articles VI and XI).

165. Many writers pay little serious attention to their Introductions, but whatever needs to be done in the way of defining the subject for the reader should be carefully done. At no time is bewilderment more fatal for the reader than at the start. If he gets into a subject with a thorough understanding, he is able to surmount more serious difficulties; but starting is as much more difficult than continuing for a reader as it is for a locomotive attached to a heavy train. Even when the reader can reasonably be assumed to have the knowledge, the Title alone may not call it into his mind. If it is briefly but clearly presented to him, he has, then, consciously in mind the exact foundation on which the writer is going to build. Any one who wishes to learn how to "interpolate" (Article VII), for example, certainly should have learned what a "table" in mathematics is and what "argument" and "function" mean; but in order to understand the process, he must have the meaning of these terms clearly before him, and by illustration or by verbal explanation the writer can put the needed facts before the reader more compactly and more exactly than the reader probably could himself. The best way to progress rapidly and surely in the explanation of a subject often is to start slowly and carefully by means of a well-planned Introduction.

166. **Conclusion.** — In technical writing a formal Conclusion (61–63) is often not necessary. Yet the effectiveness is generally lessened if the writer does not pay careful attention to the way he ends. When a piece of exposition ends, as mathematical treatises especially are apt to, simply with the explanation of a minor detail which the writer, with or without good reason, has placed as the last, it not only impresses the reader with the lack of artistic finish, but it leaves the subject out of the proper perspective, and misses the opportunity of placing the important final emphasis on some essential conception.

167. If the article is short enough for the reader to retain the whole subject in mind to the end, it is usually sufficient so to plan the treatment that the reader will have a realizing sense that the concluding statement completes the subject (Article XIX). In a longer or more complicated treatment it may be advisable to put in formal indications of progress, such as "in the first place," "in the second place"; in which case "in the last place" will sufficiently indicate the completion of the subject. This may be done even by a single word (for example, "ends" in Article XI).

168. In longer pieces of exposition the problem which the Conclusion should solve is that of ending, not with minor details, but with a broad or essential conception. Bringing together as a whole the details which have each been considered separately corresponds to the assembling of the parts of a machine, each of which has to be made separately, but would have little value or meaning unless brought together at the end. Short articles, such as have been included in the Appendix, do not need any elaborate process of assembling. A brief summary (as in Article XVI), the statement of some important general point (as in Article XVII), or even a word fortified by one or more illustrations (as in Article V) may serve

to bring the reader back from the details to a conception of the subject as a whole. If the paper is concerned with theory, principle, or method of procedure, the Conclusion may well state briefly the essential point which the reader should keep clear in his mind whatever difficulties or confusion he may get into (Article VII).

169. Still another kind of Conclusion adds to the finished explanation something which may be called its "application." The explanation may be clear enough to the reader, but it may seem to get more and more "up in the air" or detached from his personal concerns. To leave him with such an impression is unfortunate. The effectiveness of the treatment is greatly increased by bringing out as a Conclusion its meaning or value to the reader (as in Article XII). If the reader addressed is distinctly of the practical type, it is generally well to end with definite practical results (as in Article XV). Such Conclusions are similar in substance to the Introduction and at times it may seem a little difficult to decide in which division to put the "meaning or value." In the Introduction the writer must stand on the ground of the common knowledge and interests of his readers; if he brings out in the Conclusion the meaning and value of the subject to the readers, he comes back again to the same common ground. But whereas at the start the readers had not the special knowledge to be given them in the Body, at the end, as they are again led to associate the subject with their general knowledge and interests, they have in mind the subject defined and enriched by all the added special knowledge. Therefore, whatever meaning and value is needed to lead the reader to the subject should form a part of the Introduction; whatever is not, may well be left for the Conclusion, for it is this especially that the reader should carry away with him as the result of his reading.

170. In the last place, a Conclusion may be added in

some cases to "open up" the subject. When a single instrument or a single way of performing a process has been explained in the Body, it is possible in the Conclusion to suggest the character of other related instruments (as in Article II) or other processes. Sometimes it is possible by suggesting the limitations of present knowledge or attainment to open up a future of further progress and to suggest in what direction that progress will probably follow (as in Article V). Or again, after an explanation which merely enters upon a broad field, the Conclusion may suggest something of the scope of the whole field (as in Articles XIII, XXII, XXIV).

171. In all cases, after the explanation of the Body is complete, it is worth while to consider whether the subject is left in the reader's mind in the form most serviceable to him. If it is not, if the details of the Body do not build themselves up in the reader's mind into an adequate conception of the subject as a whole, if the essential point is not given due emphasis, or if the subject would profit by being brought into relation with other and broader subjects or with future possibilities, the desired turn should be given in the Conclusion.

172. **The Title.** — The Title, as we have seen (63, 159), is structurally a part of the Introduction, for it takes the first step in defining the subject for the reader. Sometimes the Title is general, as "Color Photography" (Article XI), "Multiplex Telephony" (Article XII); sometimes it is more definite, as "A New Separator for the Removal of Slate from Coal" (Article XV), or "A Boat Torpedo of Enormous Destructive Power, carrying its own Gasoline Engine and Crew" (Article XVII). If it is general, the Introduction must at once make the subject more specific. On principle, the more definite Title is to be preferred because it is less ambiguous and because it makes the preliminary explanation in the In-

troduction more simple. On the other hand, long Titles (consisting of more than enough words for a single line) do not look as well, and give the effect of being overloaded.

173. In order to decide how definite to make the Title, perhaps the best way is to consider its second use, that of attracting notice. If, in order to sell a book, it is desired to catch the unwary reader, a "catchy" title will aid. But it is of no advantage to the engineer to entrap those who do not care for what he has written. Since in most cases others have already written on his subject, it is, however, desirable to arrest attention, and this is usually best done by a Title which is short, yet definite enough both to warn off those who have no use for the subject and to attract those who would find it an advantage to read just this treatment.

Special Problems of the Different Rhetorical Forms

174. **Descriptive exposition** (79). — The only important problem special to descriptive exposition is the threefold one of naming and describing the parts and explaining their relations. Ways in which this is done are illustrated in Articles I, II, IV, V, X, XV, and XVII. In writing for general readers there is the question of the use of general or technical terms (187, 287–292), and in writing for specialists there is the question of using the exact term (223), sometimes of originating a satisfactory term (223). Each of these problems will be considered later in the sections referred to.

175. **Narrative exposition** (106). — In narrative exposition two special problems arise: 1. Where is it best to insert the descriptive parts, in the Introduction or in the Body at the place where the instruments, or other objects, are used? (89–93.) 2. When a process which may be performed in several ways is being explained, is it

better to give at each step the various ways, or to give one method complete and then explain the ways in which other methods are different? (88.) These questions have been discussed in the sections referred to and will be dismissed here with reference to Articles VII, XI, XII, XIII.

176. **Directions** (123). — In writing directions, three points should be specially observed: 1. The use of the imperative mode instead of the indicative which is employed in the other rhetorical forms represents, not only a change of form, but a change of attitude (108–110); consequently the indicative should be used in the explanatory parts, the imperative in directions only (Article VII). 2. The chief difficulty in writing directions arises from the fact that the writer who knows how, is in constant danger of emphasizing those things which seem to him important and of slighting those things which the reader, who does not know how, needs to be told (111). The only way in which the writer can be sure to avoid this serious fault is to put himself in the place of the reader and go through the whole process, in his imagination, step by step, endeavoring to do only what the directions say and in the way they prescribe. It is important to take special pains with the parts where it is difficult to follow the directions, and above all to make clear to the reader where judgment should be used and where skill is necessary. 3. In the last place, directions may or may not include full explanation (113). The unskilled workman may follow orders blindly, may do things satisfactorily without any real understanding of what he is doing or why. For the intelligent reader, directions will be more effective in proportion as they make clear just what is being done at each step and why it is done that way (Article VII). It is specially helpful if at those points where judgment should be used or where skill is necessary, the dangers are care-

fully explained and the reasons given why they may be best avoided in the way directed.

177. **Combinations of rhetorical forms** (145). — Combinations of different rhetorical forms offer no special problems in those commonest cases where they come about inevitably from the nature of the subject. For example, in Articles I and II, the general process of measuring an angle is explained in order to make clear the structure of the transit; and in Article XI the photographic plate is described in order to explain the process of color photography. Where different rhetorical forms are combined in order to give the reader a more effective knowledge of the subject by presenting it from more than one point of view (182), new problems arise. For example, it may be desired, as in Article VII, to explain a process, to give a concrete illustration of it, and to give directions for performing it. Each of these phases of the subject may be considered by itself, and in so far they are no different from other examples of the same forms; but when they are combined in this way, the question arises, In what order should they be taken up? Three principles need to be considered: 1. That division should come first which presents the subject in the form simplest for the reader to grasp. 2. That form should come first which gives the reader the broadest and firmest grasp on the subject. 3. That form should come later which may be shortened or which may be made simpler for the reader to understand because of the previous explanation. How these principles can be adjusted and what the resultant order will be must be determined in each special case.

Means of Giving Extra Help to the Reader

178. If a subject is difficult for the reader to grasp, it is not enough that he be given a logically complete explanation. He may overlook some things that the writer

can find in the explanation without difficulty, or he may be obliged to put much more effort into mastering the explanation than he would if the subject were handled at greater length. Of the various ways of assisting the reader which our study so far has discovered, five will be summed up here as the most important.

179. In the first place, it is not only important for the writer to have a well conceived plan and to carry it out consistently; it is often helpful to the reader if the *plan is indicated* to him and kept clearly before him. As we have seen (161), the plan may be indicated or fully explained in the Introduction (Article VI). The main divisions of the " details " may be suggested or explained in giving the general conception at the beginning of the Body (74, 161), and the divisions in the Body may be marked so that the reader has a clear idea of the progress he is making (Article XXIV). If the explanation is long or at all confusing, the reader is helped if at important transition points there is a brief summary of what has been explained and possibly an indication of what remains to be treated (244). All this is so largely a matter of the form of the final writing that it will be left for fuller consideration in Chapter XI (244, 265, 276–283). In simpler cases a guide-post word now and then may help the reader to keep his bearings (Article XI; note the repetition of "No colors yet"). Often the trouble which a reader finds in grasping a subject arises, not from the difficulty in mastering the steps as they are presented one by one, but from lack of opportunity to stop now and then to take account of stock, and from lack of clear indication of the main stages of the progress.

180. In the second place, it is usually an advantage for the reader to grasp a *whole conception* as soon and as easily as possible. This should be a main or essential conception in order that it may convey as much meaning as

possible. In reading an explanation it is always difficult to maintain attention and interest if the sense is long suspended; it is always a satisfaction to come soon to the completion of a conception. Then when the reader once has a completed conception, it is easy for him to build on to it other ideas. For this reason, the general should be given before the details (52, 54), (Article XXIV); the simplest method should be explained before the more complicated or more difficult (103), (Article VII); and in addressing any but specialists a concrete case (which can be grasped with its full meaning at once) should be explained before abstract laws or general formulas are given (87, 128), (Article XXIII). Often writers jump into the thick of the details at the start, or carry on the explanation of a process by detailing all the variations at each step, or give the reader first of all an abstract statement. It seems simpler to them because they already have in mind the conception of the whole. The reader has not; and to explain the subject to him adequately it is simpler, even for the writer, to present first of all and as briefly as possible a general, concrete conception which will be fundamental (Articles I, V, VII, XV, XVII, XIX).

181. In the third place, if many details are to be presented, it is helpful to the reader to *group* them (65-67). By this means the relations of the facts will be brought out much more fully, less strain is put on the attention and the interest of the reader, and his memory is aided (Articles I and XI).

182. In the fourth place, if the explanation of the whole subject or of a part of it is difficult for the reader to grasp, it is an advantage to him, though it means a lengthening of the treatment, to have the *same facts presented from different points of view* or in different relations (127). This gives all the advantage of repetition with less risk of

destroying interest ; and it has the added advantage of giving him something of that thorough understanding which is seldom gained except by viewing a subject in many ways (Article VII; compare paragraph 3 with paragraphs 1 and 2).

183. In the fifth and last place, the reader may be greatly helped by the judicious use of illustrations.[1] Illustrations are of service in five different ways: —

1. When an object is to be described, an illustration will present it as a whole, which may be referred to at the start when it is important for the reader to get a general conception as soon as possible, at the end when the details need to be assembled, and at any point in the description when the reader may need to gather together the details which have been presented but which may be slipping from his grasp (Article II, Fig. 17; Article V, Fig. 7).
2. Illustrations will often give explanation which cannot be given in words. The shape of an implement or of a part of an implement, for example, unless it is very simple, cannot be presented adequately in words, but it can be shown at a glance by a cut (Article V, Figs. 2 and 8).
3. Illustrations will always strengthen parts of an explanation which are hard to grasp (**127**) if it is possible to present the ideas through the instrumentality of lines as well as by means of words (Article I, Fig. 47; Article X, Figs. 1 and 2).
4. Illustrations will often serve as a means of presenting ideas which are not important enough to demand verbal explanation, but which it is not wise to leave to the reader's imagination to supply (Article I, Fig. 46; Article V, Fig. 16).
5. Finally, illustrations will serve to arouse and maintain an interest which perhaps would flag if the explanation were presented by the text alone (Article V; Article XVII).

[1] For the sake of brevity the word "illustration" will be used not only for the cuts in printed books, but for plates, drawings, diagrams, and "pictures" of all kinds.

The Bearings of These Suggestions

184. These principles the engineer who writes effectively applies either instinctively or as a result of careful study of his problem of expression. Those who realize that they cannot express themselves satisfactorily should familiarize themselves with the suggestions given in this chapter. The Articles in the Appendix are not presented as models; they are chosen to show that conclusions which may be reached from a theoretic study of exposition are not mere theory, but are principles observed in actual writing. It would be valuable to any engineer to criticize these articles to see wherein the principles are or are not carried out thoroughly and effectively, and to see if he could in any way apply them more effectively. Only a few samples are given here and limitations of space have made it necessary to include only short articles which do not offer the opportunities for careful construction that are presented in long treatises. The engineer would get the most help by giving some attention to the form of expression in his general technical reading. In applying these suggestions to the concrete cases of his own writing, the main thing is for him to consider the character and the needs of the readers addressed. How these vary and in what ways they should be met will be considered in the following two chapters. With them our study of structure will end.

CHAPTER IX

ADDRESSING GENERAL READERS

185. Engineers in the past have commonly felt that it was no part of their business to address those without technical training. Being specialists themselves and devoted entirely to special interests, they have found it natural to write in a language which only those with special education could adequately follow. It has been their idea that if they addressed "general readers," they were lowering themselves to the level of hack writers of so-called "popular science." But the constructions of engineers are directly or indirectly for the general public. Few of the engineering enterprises of greatest value can be carried on except through agents and representatives of the public, who seldom have had engineering training; and and in most cases the warrant for engineering work comes ultimately at least from the public. Because the engineer has not taken his full share in the general life of the community or learned to present his special interests in the language of the general readers, he has usually found himself serving under men who, having a general business education rather than an engineering education, have been able to command positions which bring greater rewards.

Of late years it has been said more and more frequently that the engineer by shutting himself up within some narrow field of his profession has seriously limited his opportunities. A single quotation from an editorial which appeared in the *Engineering News* under the date of December 16, 1909, will show the trend of ideas.

186. "This journal is only one of many which has expressed the opinion that one of the reasons engineers do not command public confidence as they deserve is their lack of training in presenting their views to the man in the street. The physician's work brings him in touch with all classes. The lawyer, while his legal technicalities are profound, must drop them when he appeals to the juror. In the same way the engineer must forget his computations and stress sheets when he addresses the public, and use the same medium of communication that the physician and the lawyer have already learned to employ skillfully."

187. In addressing the general public the engineer has *three special problems* to consider.

(1) He must always make himself clear. An illogical presentation of ideas may not baffle a reader who has special knowledge of the subject treated ; incomplete or ambiguous expressions a fellow-engineer will probably be able to interpret as intended, but to the general reader these imperfections at once become serious. Furthermore, technical terms which mean exactly what the writer wishes to express may be all Greek to the general reader, and condensed explanations which any engineer could follow may simply bewilder one who has not had technical training.

(2) The engineer often has occasion to arouse interest in subjects which mean much to him but may not appeal to others at all. In promoting public enterprises, in introducing new ideas of construction or of operation, in selling the products of engineering construction, it is always

necessary to build up an interest among people most of whom have not the knowledge of the specialist.

(3) In the last place, the engineer needs to develop this interest into conviction. He must not only interest others, he must get them to accept his ideas.

In treating a single subject, the writer may need to make his explanation clear, interesting, and convincing, and in part the same methods will serve all three ends; but in this chapter we shall consider each of the three problems separately.

Making a Technical Subject Clear to General Readers

188. Bearing of the earlier chapters. — In our theoretical study and in the practical suggestions summarized in Chapter VIII we have in a way been considering the problem of making technical subjects intelligible to general readers, for in all cases we have addressed the beginner who, though he may have the interest of the embryo expert, has only the understanding of the general reader. All the conclusions reached up to this point should, therefore, be considered in writing for general readers; to some of them, indeed, added weight should be given because of the attitude of the general reader. The engineer, even when he is just beginning his studies, may be able to enter into the details of technical subjects with little in the way of Introduction, for the natural inclinations which turned him toward engineering, his general ideas of the profession, the studies he has already begun, the students, teachers, and graduate engineers with whom he comes in contact, all help to prepare his mind for any and all engineering subjects. The general reader, on the other hand, whose life is full of other and perhaps conflicting interests may well need a longer and more elaborate Introduction (157–165). In a

similar way the student of engineering may need no Conclusion (166-171), when the general reader might profit by one which summarizes the facts for him, organizes them into a conception of the whole, points out the essential principle, or shows the bearing and the application of what has been written. The divisions in the Body (64-66) and the order in which the facts are presented (35, 48-51), not only should be logical, but should be such that the reader is not bewildered as to the development of the subject ; the subject matter should be presented definitely and concretely, and advantage should be taken of all the means of giving "extra help" to the reader (178-183).

189. **Completeness and brevity.** — The reason so many fail to make themselves clear to those not of the same profession is that they shoot over the heads of those they are addressing, assuming all along knowledge and powers of inference which their readers have not. For the general reader, much more than for the engineer, it is *necessary to give full explanation* of all the facts and of all technical terms, and to include all the steps of processes of reasoning. Completeness here as elsewhere is a relative term ; the subject must be properly adapted to the special occasion for which it is written, but when the scope of the treatment is once decided on, the first thing to be sought in order to produce clear exposition is complete explanation.

190. On the other hand, in aiming at completeness the writer may easily overshoot. The general reader has not the patience of the specialist in wading through much matter; if he is required to enter into many details, he finds that the clearness of the explanation decreases according to the multiplicity of the facts. *Everything which is nonessential for the reader, or which, it may be assumed, he knows, should be challenged, and included only on good and sufficient grounds.* Even steps in logical

processes of thought may be omitted. To do this without introducing pitfalls for the reader requires knowledge of the workings of the ordinary human mind and good judgment; in fact the difference between a successful and an unsuccessful writer for general readers depends largely on the judgment shown in deciding what to omit.

191. In spite of the best judgment, many occasions for real doubt will be found. In such cases all the special circumstances should be considered, but there are two principles which it is always safe to observe. First, the fact on which other facts or inferences to be brought out later depend should always be expressed. To take a simple example: "Of the fifty-seven miles of road to be built, seven were constructed this year, leaving fifty miles still to be built," expresses all three steps of a very elementary process of reasoning. For any one but a child it is enough to state two; but if the fact which is to receive further consideration is the amount of work still to be done, it would not be so effective to say, "Of the fifty-seven miles of road to be built, seven were constructed this year," as it would be to say, "Of the fifty-seven miles of road, fifty still remain to be built." Second, in cases of doubt it is safer to include the matter in question than to exclude it, but it should be so expressed that it will not burden or offend the reader who does not need to be told these particular facts. This may be done in five ways: —

(1) Facts which the reader may know may be introduced as explanatory, relative or adverb clauses. By this sentence structure the writer indicates that this matter is subordinate rather than an essential part of the explanation, and he avoids seeming to assume ignorance on the part of his reader. For example: "The official announcement made the other day by Viscount Morley, *as we must now call our old friend John Morley*, settled this point."

(2) Facts which are not necessary and which some readers may prefer to pass over may be inserted in curved marks of parenthesis. For example: "Thus, a solution containing 342 g. of sugar ($CH_{12}H_{22}O_{11}$), or 46 g. of alcohol (C_2H_6O), or 74 g. of methyl acetate ($CH_3C_2H_3O_2$), in 1000 g. of water, shows a depression below the freezing point of water 1.89° in each case." Such parenthetical facts are in the sentence for those who wish them, yet are so expressed that they may be entirely ignored by those who do not. It should be remembered that the structure of a sentence which contains facts expressed in this way should be complete if the parenthesis is omitted.
(3) Explanatory matter which is too long to be inserted subordinately or as a parenthesis may be dropped into a footnote (Article VIII), or if it is more than half a page in length, it may be put at the end of the chapter or as an Appendix at the end of the book. If the matter should be read by all, it is an essential part of the subject and should be incorporated as an organic part of the text; if it is not essential, and would seriously interrupt the direct development of the exposition, yet would be of value to at least some readers, it may well be inserted as a footnote or Appendix. Teachers of composition and writers upon rhetoric seldom recognize any possibilities outside the text, probably because they feel that liberty to digress is dangerous. The young writer generally needs to be required to sacrifice all things to unity; but the more mature find in footnotes and appendices valuable means of escape from the restrictions of single-line (37, 50) development of his subject.
(4) A fact already expressed which needs to be considered again may be covered at the latter point by a reference back to the place where it was first expressed. If the fact is important in its second connection, it is usually well to repeat it, because it is rare for the ordi-

nary reader to look up a cross reference. If the reader will recall the fact, provided he is told that it has already been given, or if it is something that is not actually needed at the second place, but which the reader himself might wish to look up again, it is better covered by a cross reference. (See references 37, 50, above.) In a similar way reference forward may be made to avoid repetition whenever of two points at which the reader might wish a piece of information the second is, according to the plan of the writer, the more effective place for insertion.

(5) In the last place, descriptive matter which may be helpful to a reader in connection with an illustration and yet is not important enough to be incorporated in the text may be placed as the "legend" under the illustration (Fig. 1, § 77).

In such ways as these it is possible, so to speak, to include facts for those who wish them and at the same time to exclude them for those who do not.

192. **Relation of clearness and interestingness.** — If readers were merely thinking machines, it would be enough to express whatever we have to write, clearly. Since all readers, and especially general readers, are living human beings with their likes and dislikes, the problem of making an explanation clear can hardly be separated from the problem of making it interesting. Consequently many ways in which writing may be made clear to general readers will be taken up in the following division of this chapter.

Interesting the General Reader in Technical Subjects

193. **Occasion.** — Engineers, as has been said (185), in the past have commonly been restrained from addressing any but fellow-specialists because they have assumed

that their work is with and for engineers only and because of the difficulty of making technical subjects clear to the lay mind. They have also been restrained because of the unworthy character of much that passes for "popular science." Hack writers dress up a scientific subject in a popular style and appeal to the ignorant and the half-educated. The "facts" that they present may be inaccurate, the inferences they draw or suggest are almost certainly open to doubt, and the conception of scientific study and of scientific attainment which they give is false. The fundamental defect in such writing is a confusion of the main purpose of scientific writing (5). If a writer, in dealing with a scientific subject, makes it his object to entertain, he is by that very fact undertaking to write something no self-respecting engineer would care to sign his name to (33). But this does not preclude the possibility of writing on scientific subjects interestingly. The man of technical training, engaged in technical work, is thereby interested in the subjects of his special technic. But the layman is not necessarily interested. If there is any real occasion to address him when he is not compelled by the circumstances of his own life to inform himself, the only way is first to arouse his interest in the subject. The subject is not presented that he may be interested; he is interested in order that the subject may be presented to him. The difference is of real importance.

194. Most of the great engineering enterprises which are recognized as performing public service and some which are looked on as merely business concerns now have their publicity agents, and any engineering work which depends upon the good will of the public must first gain that good will by interesting the public in the work. Even if the engineer does not care to address general readers simply that his work may be better understood and more fully appreciated, as business or publicity

agent he may find it greatly to his advantage to study the art of interesting. In working to this end he will say nothing which is untrue or misleading, he will introduce no startling or curious facts unless they draw attention to truths of real importance, and above all he will so handle the subject that it will not merely arouse a momentary curiosity, but will give some serious instruction.

195. **Difficulties to be overcome.** — If we hear two experts talking on some subject of which we have no definite knowledge, two surgeons, it may be, discussing an unusual operation, we realize that their interest is keen, but we do not ourselves share it. If we examine our attitude in the case, we generally discover that we are not interested (*a*) because we know nothing about the subject, (*b*) because we do not see any way in which it really concerns us, (*c*) because the explanations are difficult for us to follow on account of our not understanding the technical terms or not having the necessary collateral information, (*d*) because we soon forget the facts that we do comprehend, and (*e*) because we feel vaguely but strongly that it is a " dead " subject, that is to say, one that does not keep our attention alert. If these conditions prevent one from becoming interested in a subject, the problem of interesting would seem to be, in general, to write in a way to remove such conditions. How this may be done we need to consider.

196. The writer should *show his readers that, after all, they really know something about the subject.* It might be objected that in many cases the readers are probably right in feeling that they do not. But it is impossible to explain anything to one who knows nothing of the subject (158). The reader's knowledge may be elementary and crude, far from the sort that the specialist has; but to explain the subject to him the writer must start with

what the reader knows, and to interest him he must make it clear at the start to the reader that he has some real knowledge (Article XII).

197. The writer must *show his readers that they are really concerned in the subject*, that knowledge they might gain would be of real value to them. This again would seem in many cases difficult or impossible; but if that is true, it is proof that there is no justification for addressing just these readers on this particular subject. To attempt to interest anyone in a subject which is of no value to him is a waste of time; to attempt to interest without at least suggesting that it is worth the reader's while to know something of the subject is to show poor judgment (Article V, XII, XVI).

198. The writer must so *handle his subject that no difficulties are put in the readers' way* simply because the writer has not taken pains to remove them. It is stimulating to anyone to find that he is able to comprehend an unfamiliar subject, but the general reader's interest has not endurance enough to stand any severe mental strain (Articles V, XII, XVI).

199. The writer should do all in his power to *impress the facts upon his reader so that they will not be forgotten.* For an impression on the memory to be lasting, it must be definite, and since many technical facts are in themselves far from definite for the general reader, they should be presented in some graphic fashion. Present-day journalism has developed most successful means of arousing interest and of impressing the memory by the use of graphic language, pictures, diagrams, and an endless number of such means. If the " man in the street " sees in the newspaper a list giving the number of men in the armies of different countries, he may not be interested to read it, and if he is, he will not remember the figures. If with the figures pictures are given of a German, a French-

man, an Englishman, and an American drawn to represent the relative sizes of the armies, he will look at the pictures with some interest and get a definite idea which he will remember. If he is given the figures representing the expenditures of a great railroad concern for the different purposes, he will get little out of the figures and remember much less. If, instead, the relative amounts are indicated by different sized segments of a circle, each with a distinguishing color, the important facts will be impressed upon him. The extent to which the graphical presentation of ideas is carried by sensational papers in reporting a murder and the resulting trial would not be copied by an engineer; but pictures, diagrams, and similar means are employed by every publicity engineer, and their value should be recognized by everyone writing on a technical subject for general readers.

200. In order to *put life into a seemingly "dead" subject*, there are three other ways besides those just mentioned: —

(1) Things that we see done arouse and maintain our interest more easily than things we simply read about; things we succeed in doing ourselves are more interesting than things we see others do. When we address a reader in writing, we know he is not doing or seeing the things we are telling him about; but if we can so present the subject that he will, in his imagination, see the things we describe and go through the acts we explain, we shall have accomplished something. When a writer of history or fiction describes a scene or narrates a sequence of events, the distinctness with which it all rises before the reader determines largely his interest in what he reads. In a similar way, the engineer will arouse interest in proportion as he succeeds in presenting his facts concretely and distinctly so that they will stand out sharply in the imagination of the reader (Article XI).

(2) Although the reader should not be burdened unnecessarily, his interest will tend to flag if his mind is not kept active and if he is not given the satisfaction of gaining an understanding which is gratifying to his self-respect. The writer who evidently slurs over difficulties, who shows he does not feel obliged to be perfectly accurate, who condescends to his readers, intentionally or unintentionally impressing on them that he knows a great deal and cannot expect them to understand much, is sure to bore and to disgust his readers. On the other hand, he will arouse a real interest if he can lead his reader to do some real thinking and to gain a creditable understanding of a special subject in the very form and the very language of the specialists (Article XII).

(3) In the last place, the bringing out of unexpected or striking facts or of sharp contrasts is sure to arouse interest. The expected, the unvarying color, monotony of any sort can never hold the attention. The successful popular writer, recognizing this fact, fills his writing with paradoxes and contrasts. There is no occasion for the engineer to introduce "fireworks" just for effect, even in addressing general readers, but it is always legitimate to use such means to arouse interest in important truths (Article XXIII).

201. Illustrations of methods of interesting. — As an illustration, we shall apply the principles just formulated to a subject which it is safe to assume is not in itself interesting to the general reader, "Chlorine." At the start it is apparent a strong appeal must be made in the Introduction. The notion of the reader that he knows nothing of chlorine and is not at all concerned with it must, if possible, be overcome. In as far as it is possible, striking facts and sharp contrasts must be presented to drive home the important truths. In the Body, the properties of Chlorine must be explained and

something of the methods of manufacture. Other facts about chlorine and its compounds which would be of general interest could hardly be introduced in a short treatise. The technical facts should be expressed clearly, concretely, and graphically, beginning with simple experiments which the reader could perform himself and which he can see clearly in his imagination. Each division should lead unmistakably to the next, and should end with a presentation of the facts in the form and the language in which the chemist himself would record them. The Conclusion should bring the scientific knowledge imparted, which has come to be more and more technical, back into relationship with the actual uses of chlorine with which the reader should be acquainted.

202. As a result of observing these principles we may draw up an outline as follows: —

CHLORINE

INTRODUCTION. Chlorine is a chemical element.

A. Important characteristics of which are well known in the common compound, *chloride* of lime.

B. Most commonly found in its compound with sodium, common salt.

C. Though a part of a substance known from the earliest time (salt), not separated till 1774, when Scheele first called attention to it in his treatise on black oxide of manganese; and not definitely considered an element till 1810, when Davy pointed out the probability of its elementary character and gave it its name from the Greek *chloros*, greenish yellow.

D. A greenish yellow, irritating, even deadly gas, different in every way from the white solid, salt, which we use in our food.

BODY. (Chemical details.)

A. From common salt chlorine is usually made on a small scale in the following way:

I. Chemicals necessary. (Names — common, if any, and chemical — and chemical symbols.)
II. Apparatus (shown by an illustration).
III. Process.
IV. Reactions. (Given in form used by chemists.)

B. Properties.
- I. Physical.
  1. Color.
  2. Odor.
  3. Weight. (Roughly compared with that of air.)
  4. Boiling point.
- II. Chemical.
  1. As shown by action on
     - *a*. Mucous membrane.
     - *b*. Burning splinter.
     - *c*. Powdered antimony.
     - *d*. Heated copper foil.
     - *e*. Hydrogen.
     - *f*. Ink and coloring matter in cloth and flowers. (Wet and dry.)
  2. As shown by more complicated experiments.
     - *a*. Remarkably active, combining with or acting in some way upon most other elements even at ordinary temperatures.
     - *b*. In the laboratory entering into many valuable compounds and helping to bring about many important processes.
     - *c*. In nature never found free, but occurring mainly in combination with sodium; also with platinum, magnesium, and silver.

C. Manufacture.
- I. In laboratory.
  1. Directly, by the electrolytic process only. (Seldom used.)
  2. From salt, indirectly, as explained above, by first forming hydrochloric acid then oxidizing the acid.
  3. Generally, from hydrochloric acid, which is one of the commonest reagents, or from bleaching powder treated with an acid.
- II. For commercial purposes, where the aim is to produce it at the lowest cost.

1. By Deacon's process, which decomposes the hydrochloric acid by means of the oxygen of the air, passing the acid and air together through a heated tube containing clay balls saturated with a solution of copper sulphate and then dried.
2. By Weldon's process, which oxidizes hydrochloric acid by the use of manganese dioxide and treats the waste liquors so that the manganese may be used over again.
3. By the electrolytic process, which is commercial wherever the cost of the electricity is low enough.

D. Storage and transportation.

I. As chloride of lime.

II. Liquefied, in iron cylinders.

Conclusion. Use and value of chlorine and its compounds.

A. In the laboratory.

B. For the various commercial purposes.

203. **Further consideration of a few points in the synopsis.** — By calling attention to chloride of lime, disinfecting chlorides, or bleaching powders, the reader may be shown that he already knows some important facts about chlorine and might profit by further knowledge. By skillfully bringing out the contrasts between chlorine and common salt, his curiosity and interest may be aroused. Such contrasts might be merely striking were it not that they suggest to the reader the important truths that substances which we are most familiar with in our daily experience may give no hint of their chemical nature and that the chemical elements of which a substance is composed may have nothing in common with the substance as we know it in ordinary experience.

204. In the Body, division *A* might seem to anticipate division *C*, but its real object is to put the fact that chlorine may be obtained from common salt before the reader in such a simple concrete way that he can "see" the process distinctly in his imagination. For that reason it is well to give each step definitely and distinctly instead of in the brief way which would be entirely satisfactory for the chemist. If as each chemical is mentioned the symbol is also given, and then the process is fully explained, it will be possible for the reader to see the mean-

ing of the reactions stated in the form in which they would appear in a treatise on chemistry.

205. In explaining the properties, a careful distinction between the physical and the chemical is important for the beginner. The physical properties are discoverable in the first experiment of making chlorine from salt. The chemical properties might be stated at once as so many facts; but if they are brought out by means of simple experiments which the reader can easily see in his imagination, the meaning will be clearer and the facts more certain to be retained. After the general properties have been explained concretely, is the best time to give the reader those more general chemical facts which have been learned only as the result of much experimentation and research.

206. In explaining the processes of manufacture, it would not be well to go into the details that would be given in an advanced treatise on chemistry; it is enough if the broad essential features of each are explained. In dealing with the commercial processes the only point that needs to be explained is the special means adopted to reduce the cost of production.

207. **Other methods of interesting.** — Some writers on scientific subjects insert, in addition to the simple facts, much that is sometimes considered ornamentation, "literary writing." Anything which is merely ornamentation is to be condemned; but many additions which might be classed as literary writing have real and important value.

208. *Concrete examples* to make clear abstract statements are specially helpful. Each scientist works largely in an abstract world built up by him and by his predecessors and collaborators. He turns to the world of our common experience for his data, and ultimately brings the results of his researches back into the world of our daily life for application; but much of his work is carried on in his special abstract world. It does not trouble him if he goes through long processes of reasoning without referring back to experience for data or without looking forward for use and value. But the general reader, anyone in

fact who has not labored long in this particular abstract world, finds the case quite different. The abstract processes of thought of the mathematician, of the philosopher, of the electrical engineer, soon bewilder or weary anyone who is not of the profession, unless they are frequently supported by concrete illustrations which make clear how and where the data are obtained and what are the meaning and application of the results, or which bring out the meaning by analogies taken from familiar experience. For example, anyone who has not made a special study of psychology will appreciate the difference between the abstract statement of Spencer and the concrete illustrations of William James given in Article XXI. Other illustrations of the use of concrete cases and common analogies for the purpose of explanation are given in Articles VII, XXII, XXIII.

209. Closely connected with verbal illustrations are the various uses of illustrations, tables, diagrams, and other graphical means of presenting facts. Lack of space makes it impossible to illustrate these ways of appealing to the reader, but the possibilities are clearly shown in such books as "The New Knowledge," by Robert Kennedy Duncan, "A New Astronomy," by David P. Todd, or "Dynamic Rotation," by A. M. Worthington.

210. Other rhetorical, "literary," qualities of style which help to make a technical subject interesting to general readers are entirely matters of final form. The success of a writer who attempts to interest depends largely upon the skill with which he expresses his ideas. All that we have been concerned with so far is the way in which the difficulties which make a technical subject uninteresting to the general reader may be reduced by a careful building up of the logical structure. How that structure should be presented to the reader, how it should be given a final form which will secure interest, we shall consider in Chapter XI.

The Problem of Convincing

211. **Occasion.** — In many cases the engineer has to present his ideas, not only so that they will be clear, not only so that they will attract and arouse interest, but so that they will also convince the reader or hearer of their truth. In advertisements he may have to write, in letters, reports, magazine articles, or books in which he is advocating special ideas, in attempting to introduce a machine or a process, in interviews, or at meetings of societies where he appears as an advocate, and in many other ways by written or spoken word he may need to convince those whom he is addressing. In the strife for advancement, for success, this is an important means.

212. **Limitations to be observed in this book.** — Often the engineer is dealing with matters of judgment, that is to say, he is trying in a formal or in an informal way to establish what he judges to be the truth. In such cases he is using the rhetorical form argumentation, with which we have nothing to do here. We are concerned in this book only with *exposition, which deals, not with matters of judgment, but with matters of fact.* The writing of advertisements has of late years developed into an art studied by specialists; consequently, that also will not be specially considered here. Finally, in any case where it is the object to convince, much depends on proper adjustment of the expression to the person or persons addressed: in writing, the opinions, the habits of thought, the prejudices, of the special readers must be considered; if the appeal is made *viva voce*, the personality of the audience must be studied, not only to determine what is to be said, but to determine the bearing and the manner of the speaker. With these human problems we are not here concerned. There are ways in which the logical structure itself may be shaped to produce conviction, and it is to these that we now turn our attention.

213. **General plan.** — In a piece of formal argumentation, it is the special business of the *Introduction* to get the exact case before the reader, fully defined, freed from all matter which may become involved with it, but which should be excluded, and properly divided into its different phases. When a piece of exposition undertakes to convince skeptical readers that the facts presented are true, the Introduction has just about the same office to fulfill. And in exposition, as is usually the case in argumentation, the best way is to set the introductory facts before the reader in such a manner that he will feel that the whole case is put to him frankly and honestly. Any idea that the writer is a prejudiced witness or advocate will tend to make the reader question even obvious facts, and the place to disarm this opposition is at the start.

214. The *Body* in argumentation is the presentation of the arguments (inferences from facts) on the different issues; in exposition it is simply the explanation of the facts (4). But in order to present facts so as to convince the readers of their truth, certain principles should be carefully observed. The facts need to be given with perfect clearness and, as far as possible, in such simple, concrete form that the reader's attention and interest will be secured and he will be enabled to keep the whole subject in mind distinctly enough to form his own judgment of the facts. If there are spots where he becomes confused, bewildered, any prejudices he may have had at the start will be sure to suggest to him that at just these points the writer may be intentionally or unintentionally tricking him.

215. For *Conclusion*, it is probably necessary to sum up the case, as in the conclusion of a formal argument, and to present briefly and compactly all the facts which are particularly adapted to produce conviction. For this reason it may be necessary to repeat some things already

said, or even to do something not permitted in formal argumentation, to leave for the Conclusion some facts which would otherwise be considered as making an essential part of the Body.

216. Special subject to be studied here as an illustration. — The subject we shall take to illustrate methods of arranging the structure of a piece of exposition so as to produce conviction is "Marsh's Test for Arsenic." It is well known that the general public is suspicious of expert testimony and of the tests introduced in criminal court trials. The uninformed and the cynical dismiss them all as paid testimony which may be hired by either side. The attitude of the intelligent is expressed in the following editorial from the *New York Evening Post:*—

> Mr. Jerome tells us that in all his experience of experts he can "recall only one man whose testimony was radically dishonest." But no sensible critic of the expert-testimony system as it exists rests his objections on the idea that eminent professional men give testimony that is radically dishonest; the trouble is that it is not radically honest. The matter in dispute is one on which with the best of will and with no inducement whatever to partiality, a man may easily be in doubt as to the weight to be attached to each particular factor in the case; and as soon as a bias in favor of one side is furnished by the fact that you are paid by that side for your services, it is easy to deceive yourself into the belief that you are honest when the most that can be said is that you are not "radically dishonest." It is safe to say, furthermore, that something grosser than this does actually occur, too, and very frequently; namely, that the professional expert understands that, while he has no right to tell a literal untruth, it is taken for granted that he will make out as good a case as possible for his own client, instead of helping, as he should, to bring out the whole truth.

Now the problem we shall undertake to solve is this: Having in mind the common feeling of suspicion against all expert testimony, we shall try to explain the Marsh test for arsenic in such a way as to convince our readers

that this test at least is to be trusted to prove what it undertakes to establish, even when it is introduced as a part of the evidence in a murder trial. We shall not be writing argument, for we are dealing only with facts. We must recognize that many of the facts on which we are trying to build up conviction we can only assert. Assertion counts for little in argument unless it is properly supported; but the assertions given here must be accepted in good faith because they are so accepted by chemists generally. They could not be questioned by an attorney or by anyone else unless a chemist should discover new and conflicting facts. It is our business, then, to see how much we can do toward convincing our readers of the trustworthiness of this test *simply by the logical form* in which we present the facts.

217. The outline.

MARSH'S TEST FOR ARSENIC

INTRODUCTION.

- *A*. Importance of the test in cases where death is suspected to be caused by poisoning.
  - I. Arsenic, in its compounds, is a deadly poison.
  - II. Since it has legitimate uses, it may be obtained without creating suspicion and consequently may be used purposely as a poison, or it may by accident become the cause of death.
  - III. In case of death which possibly resulted from poisoning, it is important to know whether or not there is arsenic in the body.
- *B*. Scope of the test.
  - I. Whether the death was the result of poisoning or not is for medical authority to decide.
  - II. Whether the death, if caused by poisoning, was willful murder or accidental poisoning, is for the court to decide on all the evidence.

III. Marsh's test undertakes to show simply whether or not arsenic is present in the portion of the body submitted for analysis and what quantity, if any, is present.

C. Object of this paper. The object of this paper is to show that Marsh's test is a trustworthy qualitative and quantitative test for arsenic.

BODY. (The chemical processes.)

A. The qualitative test.

1. (The principles of the qualitative test.)
   - *a*. Arsenic in solution readily unites with nascent hydrogen forming a gas, arsine.
   - *b*. The presence of arsenic in the gas is readily detected on passing the gas through a hot hard-glass tube.
   - *c*. No other element will so act except antimony, which will also unite with hydrogen and form stibine.
   - *d*. So that the test consists in putting a solution of the suspected substance into a flask in which hydrogen is being generated and examining the gas which is formed.
   - *e*. The only serious difficulty is in distinguishing arsine from stibine.
2. The process of the test. (To be explained fully.)
   - *a*. The formation of the solution.
   - *b*. The generation of hydrogen.
   - *c*. The introduction of the suspected solution.
   - *d*. The testing of the gas to detect the presence of either arsenic or antimony. (Deposit in form of mirror.)
   - *e*. The testing of the deposit, if any is formed, to determine whether arsenic or antimony is present, or both.
     - *x*. Color.
     - *y*. Volatility.
     - *z*. Action under reagents.

B. The quantitative test. (Outlined in a similar way. Omitted here for the sake of brevity.)

CONCLUSION. The trustworthiness of the test.

A. (As a qualitative test.)

I. Since no other chemical than arsenic and antimony will thus combine with hydrogen, and since the deposits of the two elements show distinct characteristics when treated as explained above, the qualitative test is trustworthy, if no arsenic is introduced in any other way than in the portion of the body submitted for testing.

II. Since arsenic may be present in some of the chemicals used and especially in the glass apparatus, it is necessary

1. to use the purest chemicals and apparatus obtainable and to compare the results of the test of the suspected solution with a "blank" test, that is, one in which all the chemicals and the apparatus employed in the test are used but the suspected substance is not introduced; or, if the amount of arsenic is so small that an extremely accurate test is necessary,
2. to test the apparatus and each of the chemicals in a blank test and then use for the test of the solution no piece of apparatus or chemical which has not been shown to be strictly free from arsenic.

If this precaution is taken, there can be no doubt as to the accuracy of the qualitative test.

B. (As a quantitative test.) The test is sufficiently accurate quantitatively since it usually takes at least 125 milligrams of arsenic to cause death, while the test will detect as small an amount as .001 milligram.

C. (As a check on all bias on the part of the expert.)

I. Some expert tests (handwriting tests, for example) rest almost wholly on the judgment of the expert, who is inevitably more or less biased.

II. The Marsh test rests rather upon the observation of definite facts (for example, whether

or not a deposit is dissolved by a given reagent).

III. Furthermore, the different tests are varied and appeal to the senses of the experimenter in such different ways that they form adequate checks on unintentional errors of observation

218. **Summary.** — To present other subjects convincingly would inevitably call for treatments which would seem different, but the principles which we have formulated apply equally to all. The chief difference between exposition which aims to convince and argument, namely, that exposition deals with facts, while argument deals with matters of judgment or of opinion, affects principally the character of the Body. In each form the Introduction must get the case clearly before the reader, and the Conclusion must gather together briefly all the points, or the main points, which make for conviction. The space limitations of the Appendix make it impossible to include long enough articles to illustrate adequately processes of conviction, but Articles XVI and XX, though in part argumentative, deal mainly with facts which the writers are presenting in order to convince their readers.

The Essential Principle to be Observed in Addressing General Readers

219. If the engineer has occasion to write for general readers, he must know his subject thoroughly, but more than that he must have a thorough knowledge of common human nature. Realizing that he is addressing those who of themselves are not concerned or interested in his subject, he must express himself clearly, interestingly, and convincingly to them by shaping all he writes according to the knowledge, interests, and habits of thoughts of his readers.

CHAPTER X

ADDRESSING SPECIALISTS

Ways in which addressing specialists is a simpler problem than addressing general readers, § **222**.
New principles which should be observed, §§ **223–225**.
Ways in which the problem of addressing specialists is similar to that of addressing general readers, §§ **226–231**.

220. Much of the writing of the engineer is addressed to fellow-engineers. He may not contribute to the reference libraries of experts, but if he is alive to his opportunities, he will publish articles or notes in the technical magazines of his special profession. If he is employed on any great construction work for city, state, or nation, he may have to write annual reports; and even if his work is on a much smaller scale, he will probably be required to make daily or other short reports, or he may have to write the specifications for contracts. On many occasions such as these and even in the simpler and more commonplace work of writing his professional letters, he will meet problems which we have not yet considered, or which we have not solved as they should be in addressing specialists.

221. In this field of writing the opportunities for the teacher of English to give instruction are strictly limited. Only a civil engineer can teach one how to keep notes for the city engineer's office; only an electrical engineer or a writer on electrical subjects can teach one the symbolic forms of expression used in dealing with electrical subjects. The proper way to record the results of a boiler test should be taught by a mechanical engineer. The

form of the annual report of a railroad should be determined by a railroad expert. In all cases the way in which the facts of a profession should be recorded and transmitted within the profession should be taught along with the methods of getting the facts. Yet the principles to be observed in addressing specialists are largely the same as those to be observed in addressing more general readers; all that is needed is to apply the principles according to the special conditions. The general way in which this should be done we may well consider here.

Ways in Which Addressing Specialists is a Simpler Problem than Addressing General Readers

222. Many things which the writer should do to assist general readers in getting a clear understanding of a technical subject, he does not need to do when addressing specialists. There is seldom occasion to build an elaborate foundation in the Introduction because the reader already has the required knowledge. It is not necessary to seek special means of arousing interest in the subject, for it is addressed to those only who are professionally concerned. In most cases there is no need of adding a formal Conclusion, either to round up the subject into a whole or to show the value or application of what has been said. The specialist will generally be able to do all this for himself. It may not be necessary to explain the general principle or the general structure at the start, for the reader may already have that knowledge, in which case he can enter at once into details. What the specialist wishes is a clear and concise statement of the facts; anything in addition to such a statement which the reader does not actually need is not only wasted, but makes the presentation less acceptable and, it may be, less easy to grasp.

New Principles Which Should be Observed

223. Anyone who addresses specialists on a technical subject should use the *special language* of that particular technic (compare Article XIII with Article XII). This means, not only that he must use the proper technical terms and expressions, but that he must adopt the mode of expressing ideas peculiar to the field in which he is working. The mathematician has his formulas and his special signs; the chemist has his symbols and his equations; the topographer records his ideas on maps, the draughtsman on plates, in a language which to the uninitiated may mean little. In many cases technical information may be conveyed wholly in some tabulated form. Each profession has its peculiar forms of expression and even its individual habits of thought. Some of these professional habits may be improved on by anyone who has thoroughly studied the underlying principles of expression; but in no case should an engineer attempt to address specialists without having first mastered their language (Articles IV, X, XIII, XV, XXII, XXIV).

224. Ideas which could be made clear to general readers only by the use of many words can be expressed briefly for the specialist; and the insertion of words, facts, or explanations which are not required is a serious offense. The writer needs to be a good judge of what his readers already know; he needs to confine himself strictly to those phases of his subject which are of real value to his readers; he needs to take advantage of all the symbols and of all the possibilities of presenting ideas by diagrams (Article XXII) or in tables (Article IV); and in the last place he needs to take all the logical short cuts possible without making it difficult for his readers to catch his meaning. One of the best means of developing the art of writing concisely is in business and professional

correspondence, for the essense of good letter writing, the expression of the desired ideas clearly and completely in as few words as possible, is the virtue which the specialist requires above all in his technical reading.

225. *Flights of the imagination and expressions of feelings which are not of real assistance to the readers* in understanding the facts should be rigidly excluded. To most who are addressing specialists it is not necessary to emphasize this requirement. Yet now and then we find technical treatises or magazine articles in which the writer has inserted imaginative reflections, quotations, literary allusions, or elaborate figures of speech with the evident purpose of ornamentation. There are subjects in which free play of the imagination is natural, inevitable for anyone whose mind has not become the treadmill of narrow specializing; and the results instead of distracting the reader's attention help to hold it closely to the subject. Such natural expressions are not to be confused with the consciously elaborate imitations of the writer who strives for effect. More dangerous still are expressions of personal feeling in serious composition. Great occasions compel even the expert scientist to forget that he is, in as far as he is an expert, only a precise thinking machine, and lead him to express the deep emotions which he as a man feels in the presence of the facts. Even on such occasions, however, the English-speaking writer is less inclined to give free rein to his feelings than the Frenchman (Article XIV). In most cases the facts, if properly expressed, will themselves produce the appropriate emotion in the reader. In business letters, especially, anger, contempt, distrust, or any feeling of the sort is better suppressed or indicated only by the facts which arouse the feeling in the writer. There is much greater danger of being seriously misunderstood when emotion is expressed in writing than when it is expressed orally; and the writer will be surer of

having nothing to regret later if unkindly feelings are carefully restrained behind the facts which have called them forth.

Ways in Which the Problem of Addressing Specialists is Similar to That of Addressing General Readers

226. There are, then, some things which need careful attention when addressing general readers which the writer does not have to consider when he is addressing specialists; and there are some things to which he has to give special attention when he is writing for those who are already at home in his field. In general, however, the problem is the same in the two cases. The danger is that the writer will fail to "look before he leaps" (152, footnote), and will not do what is in his power, and what, therefore, he should do, to aid his readers in getting his ideas accurately, completely, with the least waste of effort. Many things written for experts may be read by others, and the advice Mr. Richard K. Meade gives to chemists[1] should be carefully considered by everyone writing on technical subjects: "Don't be afraid of being too elementary. The vast number of men who buy a book are not experts and they want information from A to M as well as from N to Z." Even in the case of contributions to technical magazines or of reports to the head engineer, where elementary explanations are not needed, there is no occasion for ignoring principles of expositional writing.

227. There is always need of careful planning; the only difference in addressing specialists is that it is planning for those who already have exact knowledge of the general subject of which the particular subject with which the writer is dealing is a part. The facts should

[1] "The Making of a Technical Book," *The Chemical Engineer*, December, 1908.

be presented in a logical order (48-54), for there is no reason why an expert, any more than a beginner or a general reader, should be asked to waste time and effort following the chance order of a rambling writer. The subject should be treated completely (34) and the facts should be properly coördinated (42) and subordinated (43). In those cases where the readers presumably already know a great deal about the subject, it requires skill to determine just how much constitutes completeness, but this is no justification for giving even experts fragmentary treatments. The daily report might seem to be an exception, but we should bear in mind that the single report is but a part of the combined reports on the whole job, and that the order of presentation in this case must follow strictly the sequence of the day's work.

228. As a general principle it is better to consider that an *Introduction* is always necessary. In certain cases, as we have seen (159), the Introduction is expressed fully enough by the Title; but usually a few words more are needed not so much perhaps to give preliminary explanation, as to define the subject. The Title itself may include terms which require definition ; the subject, as it is to be treated in this particular case, may need to have its bounds carefully marked out; or to be differentiated from other subjects which may be involved with it in the minds of the readers. In many cases it is worth while to introduce facts in the Introduction that the readers undoubtedly are already familiar with, in order that they may have actually before them at the start a concise and accurate statement of the case (Article XXII). In other instances the importance of the subject or the fitness of the author to deal with it may need a few words. In business letters the first words should form an Introduction which indicates to the receiver at once what the business is with which the letter deals and how it is con-

nected with the previous knowledge or interests of the one addressed. In various ways, even in writing for experts, a carefully planned Introduction may be one of the best helps in presenting a subject concisely (Articles X, XII, XIII, XV, XVI, XX).

229. A *Conclusion* is not so commonly required as an Introduction, for the specialist is generally able to shape the subject matter of the Body to suit his own needs. But it may be a help to him to have a complicated subject summed up at the end, to have emphasis laid on the important point, or to have the subject "opened up" so as to suggest definitely in what direction progress may be made in the future (Articles XIII, XI, XVI, XVII, XXII, XXIV).

230. On the subject of *accuracy* it might seem as if nothing need be said to those who are writing for specialists. The physician, the minister, the lawyer, may act on a false assumption and not be detected or even may not become aware himself of his error ; if the engineer founds his action on a misjudgment or on inaccurate data, he is far more certain to be exposed by the results. In writing, even if he were to feel that he might distort the truth to interest general readers, he knows how dangerous it would be in writing for his fellow-engineers. But by many it is the importance of having accurate facts that is realized, not the importance of expressing them in accurate language. Finding it a slow and painful process to express their ideas in words which mean exactly what they intend, many do not strive for that kind of accuracy, and justify themselves on the ground that their readers will know what they mean. Would a lawyer be satisfied to put the burden of getting an accurate understanding thus on the reader? It is true the lawyer's writing is liable at any moment to be scrutinized by one who would strive to gain some important

advantage by interpreting it in a way different from that intended by the author; and it might seem that the engineer never has to defend himself against such malicious intent. His readers, it would be said, will always strive to get the real meaning. But that is not in all cases true. If he writes specifications for engineering contracts and cannot make complete and accurate statements of the intent of the contracting parties, he may cause the loss of much money through misunderstandings which he has made possible or through the opportunities which he has left for those who would attempt to defraud.[1] If he applies for patents, he will probably employ a patent lawyer to write the specifications for him (Article X), but if he does not know himself exactly what he wishes to say, and how he can, under the guidance of the lawyer, put his

[1] "Primarily, they (specifications) should give a clear and concise description of the work, first when considered as a whole, and then in detail, no part being slighted in this description. It will not answer for the engineer to suppose that the contractor will do things as a matter of course, but he must produce a specification that will *insure* their being done.

* * * * * * * *

"Again, specifications should be written in simple, plain language without any attempt at rhetoric. All verbs should be complete, and no words should be omitted on the assumption that they are understood. Of course, the law will interpret a contract or a specification in accordance with what the court decides is its spirit, but an engineer should not rely upon this to guard against omission. If the specifications are properly prepared, there should be no occasion for appealing to the courts to decide what is or is not the spirit intended. While such documents should be comprehensive, they should not be verbose, and, above all things, they must not be ambiguous. Short sentences and simple words are preferred. Punctuation and grammar, while usually and erroneously considered of minor importance in an engineer's practice, certainly play an important part in this particular kind of literature. The meaning of a sentence can easily be distorted, or even entirely changed, by the placing of a comma. Do not fear to repeat the same words or phrases over and over again in your specifications, if you find they best convey the idea you have in mind. This may involve occasionally some lack of euphony, but that can very readily be dispensed with in writings of such prosaic nature." — "Specifications and Contracts," by J. A. Waddell, C. E., D. Sc., LL.D.

exact ideas into words, he will be liable to be seriously disappointed later as to the value of his patent rights. In general, however, the reason the engineer should strive to express his ideas accurately is not that he may himself lose if he does not, but that it is his business to convey ideas without putting any unnecessary burden upon his readers.

231. At this time a great deal is being said about *efficiency* in all kinds of business and professional activity. Some writers for specialists have not learned what efficiency in writing means. To them it is economy of time in writing ; or, if they consider the reader at all, it is measured almost wholly in terms of conciseness. As we have seen (36–38), it is a waste to make readers wade through unnecessary words or through explanations or digressions which might be omitted ; but it is just as much a waste to compel them to study out ideas which are omitted or merely hinted at when they should have been fully explained, or to make it necessary for them to discover the meaning intended when the thought is inaccurately or illogically expressed. The fact that the specialist may be able to get the correct ideas finally, or that he may not even be aware that he is forced to do unnecessary work, does not make the writing any less efficient, any more than the fact that a department of railroad work is carried on without anyone's realizing that there is waste makes the work of the manager efficient if he so plans that those under him have to spend unnecessary time or energy.

The General Problem of Addressing Specialists

232. Efficiency of expression is to a considerable extent a matter of sentence structure, choice of words, and other things which are parts of the shaping of the final

form. These questions will be discussed in Chapter XI. But the foundation must be laid in the structure. In writing for specialists, no less than in writing for general readers, it is necessary to consider the readers carefully, to decide what it is safe to assume they already know, what they need to be told, and how they may be addressed most effectively. Even specialists are sharers in common human nature, but at the same time they have well-developed habits of thought and of expression peculiar to their special subjects; both of these things the writer should take into account in order that he may present his subject in a way to give the largest amount of information with the smallest expenditure of the reader's effort.

CHAPTER XI

THE FORM OF THE FINAL WRITING

The relation of the final writing to the synopsis, § **233**.
Two general problems which arise in shaping the final writing, § **234**.

233. Up to this point we have been concerned with the problems which are met in selecting the facts to be presented to the reader and in determining the ways in which those facts should be brought into relationship one with another. This is an important part of technical composition, as important as the selection of the materials and the designing of the structure of a building. If this part of the work has not been adequately done, the faults of a piece of technical writing cannot be removed by touching up the manuscript here and there. As the writer builds up his logical structure he may carry it all in his head; if he records it on paper and does no more than we have suggested so far, the result will be some form of synopsis. In order to express the ideas adequately for the reader, they must be developed into the "form of the final writing." In making a synopsis, the writer must think out or write down a logical structure shaped entirely for the benefit of the reader, but the form is not one that custom permits for final presentation; the ideas are not necessarily expressed in sentences, and the words chosen may not be those best suited to convey the ideas to the readers. With the problems which are not met in writing synopses, but which should be solved in giving final expression to ideas, we are concerned in this chapter.

234. Since synopses are used only in special cases in published works, the question arises at once, What becomes of the logical relationships which it is the main purpose of the synopsis to indicate? If they are not of value to the reader, there would seem to be little occasion for the writer's spending his time to build them up. If they are not only a help to the writer in thinking out his subject, but are important after they are once determined, it would seem a serious loss if the reader does not get them. In the first place, then, we shall consider ways in which logical structure may be indicated to the reader. In the second place, since the choice of words and the construction of sentences (which do not have to be finally settled in writing the synopsis) must be determined in the final writing, we also need to consider what rhetorical principles, aside from those which determine the logical structure, should be observed in the final writing.

THE FIRST PROBLEM

Ways in which Logical Structure may be indicated to the Reader

- General considerations, §§ **235–238**.
- Illustrations of ways of indicating structure, § **239**.
  - The general plan of a book, §§ **240–245**.
  - Chapters, §§ **246–250**.
  - Paragraphs, §§ **251–266**.
  - Sentences, §§ **267–270**.
  - Punctuation marks useful in indicating structure, §§ **271–275**.
  - Other means of indicating structural relations, §§ **276–285**.

235. **Failure to indicate structure.** In some technical writings we fail to find indication of the logical structure, not because it cannot or should not be indicated, but because the writer has failed to give the reader the needed help or even because he has failed to work out the structure for himself. Too many technical books and magazine

articles are written without sufficiently systematic planning, consequently they are more difficult to read than the nature of the subject warrants. No mature and serious seeker for information wants all the work done for him; he expects and desires to put real thought into his reading. If he does not, he can get little from reading, for the mind is not a reservoir into which learning can be poured. But the reader does not want and should not be asked to spend time and effort trying to decipher what the writer is attempting to do, why he is taking up this point or that at just this time, or in what general direction he is proceeding. The form of the expression should be such that the reader can keep his bearings without having his attention distracted from the subject matter.

236. **The suggestion of structure.** — In order to make structure clear to the reader, it is not always necessary, however, to label it at every step. We can be guided by suggestions which we take unconsciously, as well as by finger-posts. If we are in the habit of going through a certain tangle of crowded streets and lanes every day, we can find our way and avoid obstructions even though we are entirely absorbed in conversation as we walk. Our senses are taking in "signs" all the way, nevertheless, and are directing the muscles used in walking accordingly, as we realize if the signs happen to be blotted out by a thick fog. So in reading, without giving any special attention to the structure, we may gather suggestions as we proceed so effectively that we have no difficulty in keeping our bearings. In some cases the structure needs to be labeled or even carefully explained, but in general it is enough if the reader gets an understanding of the relations of the ideas by suggestion.

237. **The whole structure need not be indicated at the start.** — Seldom except in the case of subjects which are to

be studied, is anything like a formal synopsis or outline of the book, the chapter, or the article, printed at the beginning. The reader is helped if he is given at the start a general notion of the plan of the book ; but if he were given the whole plan in detail, he would not read it, much less remember it. Certain other indications of the relationship of part to part he may need to get here and there in the course of his reading, and they should be given at just the points where they are needed.

238. **The ideal arrangement.** — The ideal, we may conclude, then, would be this : first, to have the plan of presentation carefully and thoroughly worked out by the writer, that he may be sure of presenting what he should and in the best form ; secondly, to have enough of the plan explained at the start so that the reader may begin intelligently, and the rest indicated at the proper places either by suggestion or by formal explanation.

ILLUSTRATION OF WAYS OF INDICATING STRUCTURE

239. To illustrate the various ways of indicating logical structure we shall examine in some detail a single book, "The Elements of Sanitary Engineering."[1] This is a textbook of moderate length, and deals with a subject which is simple enough to be critically examined even by one who has not studied sanitary engineering. Furthermore, it is carefully constructed so that the logical relationships are satisfactorily developed and indicated for the reader.

The General Plan of the Book

240. **Indicated in part by the "Contents."** — Just as the careful writer shapes the general plan of his work before he begins to write, so the intelligent reader instinctively

[1] By Mansfield Merriman, formerly Professor of Civil Engineering in Lehigh University. Third edition, 1906.

endeavors to discover the range of a book and its general method of treatment before he begins to read. Inevitably he looks first at the table of contents. In "Sanitary Engineering" we find the chapter headings to be the following: —

I. Sanitary Science.
II. Water and its Purification.
III. Water-supply Systems.
IV. Sewerage Systems.
V. Disposal of Sewage.
VI. Refuse and Garbage.

241. An examination of these titles leads to the following inferences. Since the subject is "Sanitary Engineering," the first chapter, dealing with a more general subject, or at least one not to be specially treated in this book, must be introductory. The remaining five chapters are manifestly Body. No Conclusion appears. The Body is not only divided into five parts, indicated by chapter divisions, but these group themselves, by their titles, into two larger divisions: the first (Chapters II and III) dealing with "water" and the second (Chapters IV, V, and VI) dealing with the disposal of waste products. From the table of contents, therefore, we are enabled to make out the following outline of the book: —

INTRODUCTION. Sanitary Science.
BODY. Sanitary Engineering.
  A. The supply of water.
    I. Water and its Purification.
    II. Water-supply Systems.
  B. The disposal of waste products.
    I. Sewerage Systems.
    II. Disposal of Sewage.
    III. Refuse and Garbage.

242. **Further indications in the text.** — If the reader wishes a more complete idea of the method of treating the subject, he would certainly turn to the beginning of the

introductory chapter. There he finds, in this book, an article labeled "Introduction" (Article XVIII in the Appendix). In this the author is dealing entirely with definitions, as we should expect; definitions of sanitary science, of civil engineering, and of sanitary engineering. The definition of sanitary science concludes with a statement of the scope of the book in which the twofold character of the sanitary constructions to be considered is explained. In other words, the main divisions of the Body which we found to be suggested by the titles of the chapters are clearly indicated at the beginning of the Introduction. The rest of Chapter I, as shown by the titles of the "articles" (247) which are printed in the Contents, deals with the general principles of sanitary science on which the work of the sanitary engineer rests. The titles of the chapters, as we have seen, give no indication of a conclusion, but if we turn to the last paragraph of the last chapter, we find a summary of the scope and importance of the work of the sanitary engineer by means of which "the public health is promoted and the world is rendered stronger and better."

243. General outline of the book. — What we have discovered about the structure of the book from reading over the titles of the chapters and the first two pages of the text, we may express in the following outline: —

ELEMENTS OF SANITARY ENGINEERING

INTRODUCTION. Definitions. CHAPTER I.

A. Definition of the subject. ARTICLE 1. Introduction.

I. Sanitary science embraces those principles and methods by which the health of a community is promoted and the spread of disease is prevented.

II. Civil engineering is the art of economic construction, that is, the art of making structures for the public use at the minimum cost for installation and operation.

III. Sanitary engineering is that branch of civil engineering which is concerned with the constructions for promoting the health of the community. These constructions fall into two classes.
1. Water supply.
2. Sewerage.
IV. With these two classes of constructions the following chapters are to deal.
B. Explanation of the general principles of sanitary science as far as they underlie sanitary engineering.
I.
II. etc. Articles 2–14.

Body. Detailed explanation of the two classes of constructions.
A. Constructions for supplying pure and abundant water.
I. Water and its Purification.
1.
2. etc. Chapter II.
II. Water-supply Systems.
1.
2. etc. Chapter III.
B. Constructions for an efficient system of sewerage.
I. Sewerage Systems.
1.
2. etc. Chapter IV.
II. Disposal of Sewage.
1.
2. etc. Chapter V.
III. Refuse and Garbage.
1.
2. etc. Chapter VI.

Conclusion. The scope and importance of the work of the sanitary engineer by means of which "the public health is protected and the world is rendered stronger and better."

244. Summary of methods of indicating the general plan of a book. — In "Sanitary Engineering," the reader is enabled to get a clear idea of the plan of the book at the start, for it is suggested to him by the chapter headings and explained in the introductory article. As he reads,

the plan is kept before his mind by the titles of the chapters. The whole first chapter he knows is introductory. The Body, he has been told, deals with two classes of constructions, and the fact that the third and fourth chapters together deal with the first class of constructions (water supply) is indicated by their titles, each of which contains the word "water." It is a simple matter to infer that the remaining chapters deal with the second class of constructions; but the division between Chapter III and Chapter IV is much more important than the division between Chapter II and Chapter III, and the reader might overlook that fact as he reaches the end of Chapter III. For this reason the author emphasizes this division, not at the beginning of the book, where the structure is clear enough, but at the end of Chapter III. The last paragraph in Chapter III briefly sums up the points which have been explained in Chapters II and III and ends with the following: "The first part of the construction work of the sanitary engineer is done. But the clear and pure water is rendered immediately impure by its use, and hence the second part of his work is to follow, whereby the foul water or sewage is to be removed from the town in such a manner as to still further promote the health of the community."

245. If a book is to be studied, or if the method of treatment is in any way peculiar or difficult for the reader to grasp, it may be worth while to indicate the plan by an outline, by synopses, or by detailed explanation in the Introduction. In other cases it is enough to suggest the plan in some such way as that adopted in "Sanitary Engineering," at the start and at any places in the Body where it is advantageous to the reader to have the plan in mind. The value of any book is much greater to the readers if they get the subject, not as separate facts, but as a fully appreciated organic whole.

Chapters

246. Chapters need to be considered in two different ways. In the first place, they are parts of the whole book and as such their relationship should be indicated clearly in the general plan, as we have seen the chapters of "Sanitary Engineering" are. In the second place, they are themselves units, and as such have inner structure, which we are to consider next. Since each chapter after the first depends generally upon those preceding, we can get a clearer idea of chapter structure if we analyze the first in "Sanitary Engineering."

247. **Division into "articles."**—Since the author in this case has divided his chapter into "articles," and has included a title for each article in the table of contents, he has given us means of gathering a general idea of the contents of the chapter before reading it. The articles of Chapter I are entitled as follows: —

1. Introduction.
2. Historical Notes.
3. Classification of Diseases.
4. Statistics of Mortality.
5. Bacteriology.
6. Organic Matter.
7. Filth and Disease.
8. Impure Air and Disease.
9. Drinking Water and Disease.
10. Matter in Natural Waters.
11. Chemical Analysis of Water.
12. Biological Analysis of Water.
13. Interpretation of Analyses.
14. Results of Sanitary Science.
15. Exercises and Problems.

248. **Outline of the chapter.**—Here again we find clearly indicated an Introduction (Article 1), a Body, and a Conclusion (Article 14). Of the structure of the Body, we get some clear indications. Article 2, which deals with

the past, stands out in distinction from Articles 3–13, which deal with present-day sanitary conceptions. The titles of Articles 3 and 4 suggest that they are to explain what the diseases are with which the sanitary engineer is concerned. Articles 5, 6, 7, evidently explain the origin of these diseases, and Articles 8 and 9 indicate that the sources of disease with which the engineer is concerned are "impure air" and "drinking water." Articles 10–13 take up the special problems of drinking water. Article 15 is clearly no part of the explanation. As a result of this examination, we may outline the chapter as follows: —

SANITARY SCIENCE

INTRODUCTION. (Definitions. To be studied later, § **254**.) ARTICLE 1.

BODY. The principles of sanitary science which underlie sanitary engineering.

- *A*. Sanitary science in the past. ARTICLE 2.
- *B*. Sanitary science at the present time.
  - I. Classification of diseases.
    - 1. (General classification.) ARTICLE 3.
    - 2. According to statistics of mortality. ARTICLE 4.
  - II. Origin of diseases with which sanitary science is concerned.
    - 1. Bacteriology. ARTICLE 5.
    - 2. Organic matter. ARTICLE 6.
    - 3. Filth and disease. ARTICLE 7.
  - III. Sources of disease with which the sanitary engineer is concerned.
    - 1. Impure air and disease. ARTICLE 8.
    - 2. Drinking water and disease. ARTICLE 9.
      - *a*. Matter in natural water. ARTICLE 10.
      - *b*. Analyses of water.
        - *x*. Chemical analysis of water. ARTICLE 11.
        - *y*. Biological analyses of water. ARTICLE 12.
        - *z*. Interpretation of analyses. ARTICLE 13.

CONCLUSIONS. Results of sanitary science. ARTICLE 14.

249. In order to get a more complete understanding of the structure of this chapter, we should need to read a part of the text, especially Articles 3 and 4, which explain the kinds of diseases, and Article 7, which explains the sanitary conditions against which the engineer has to work. Such knowledge of the structure of the chapter we get as we read, and we do not need it till we reach the place where it is given.

250. **Summary of methods of indicating the structure of chapters.** — If a book is to be studied (245), it is often helpful to place at the beginning of each chapter a brief outline, and, if the subject is involved, it may be worth while to explain fully in this outline the method of treatment. In general, however, no such formal explanation is necessary; it is enough if the author has carefully constructed his chapter and has given the reader suggestions of the relationship of the different parts at the points where such assistance is needed. The Introduction should make clear just what the chapter is to deal with, and the Conclusion may sum up the results or give the proper final turn to the explanation. The main divisions of the Body may be explained in the Introduction; if not, they should be suggested to the reader where the transitions occur, provided there is any important grouping of the facts. It should be observed that chapters are similar in form to magazine articles, the main differences being that a chapter may distinctly depend upon other chapters preceding or following, and that the article does not in any case have an outline prefixed. Other points in relation to the indication of the structure of chapters or of short articles are considered in §§ 276-285.

Paragraphs

251. Within a chapter, or a whole article not divided into chapters, there are different ways of indicating divi-

sions or groupings of details; but the one which is commonest, which, indeed, is used on all occasions, is the paragraph. Every rhetorical form of composition makes use of the paragraph, but in different forms it is shaped according to different principles. One need not have made formal study of composition to have observed that the paragraph in an argument is determined on different grounds from a paragraph in a description or in a story and that different facts are taken into account in paragraphing narrative and in paragraphing dialogue. We have nothing to do here with the paragraphs in literary writings; we shall analyze those only which are used in the one form of composition — exposition.

252. **False conceptions of paragraph making.** — Since a person can hardly come to maturity without having observed that writing is divided into paragraphs, no one would entirely avoid the use of paragraph divisions in writing. Nevertheless, there are those who think that if they begin a sentence a little in from the left margin, they have made a paragraph. Probably they realize that they should thus indent when they "begin a new subject"; but often that is all paragraphing means. According to this conception, the subject on which one is writing is like the wire fed into a nail-making machine, which as it is pushed along is chopped off into short lengths. Crude as this conception is, it seems to have shaped the paragraphing in a good deal of current technical writing. If a writer is told that his paragraphs are faulty, he may ask, "Well, where should they be made?" He feels that if he has not chopped at the right place, all that is necessary is to chop somewhere else. Indentation, it should be remembered, simply *marks* the paragraph. If satisfactory paragraphs result from indenting as one writes, it is because in one way or another they were previously made in the composition of the subject.

253. Method of studying paragraph structure. — In studying the structure of paragraphs we shall assume that there is no division of the chapter (or of the whole subject, if it is a short treatise) formally marked except the paragraph. Since in "Sanitary Engineering," from which we are taking our examples, the chapters are divided into "Articles," we may treat the article as if it were a whole chapter. It is evident that whatever paragraphs mean in indicating structure, they stand here in the same relation to the "articles" that they do to larger wholes in those cases where there is no division into articles, sections, or parts. Like chapters, paragraphs should be considered in two different ways: first, as parts of the larger whole; and, second, as units which have inner structure of their own.

254. Outline of Article 1, "Sanitary Engineering" (Appendix, Article XVIII). — To illustrate the relation of paragraphs to the larger whole, we may take as an example the first article in the book we are analyzing, which we have found gives certain preliminary definitions. On examination, we see that the article defines, (1) sanitary science in general, (2) the specific work of sanitary science, (3) the parts of sanitary science which need consideration in the chapter to which this article is an Introduction, (4) civil engineering, and (5) sanitary engineering. In any writing which is so distinctly a part, leaning on to what follows rather than standing on its own legs, we cannot expect to find anything like Introduction, Body, and Conclusion; yet we may outline the article as follows: —

A. Sanitary science.
  I. General definition.
  II. Distinction between sanitary science and hygiene.
B. The work of sanitary science.
  I. Includes: — 1–10

II. Depends upon
  1. Six sciences.
    a–f.
  2. Five professions.
    a–e.

C. The part of sanitary science considered in this chapter (that which concerns sanitary engineering) includes: —
  I. Not — but —
  II. Not — but —
  III. Not — but —
  IV. Not — but —
  V. Not — but —

D. Civil Engineering is —.

E. Sanitary engineering is —.

255. **Relation of the paragraph to the next larger division.** — It will be seen that this article is made up of five topics, which are indicated in the outline by the divisions marked with capital letters. These appear in the final writing as paragraphs. Such a simple scheme is not always practical; in many cases each of the main divisions cannot well be put into a single paragraph, and consequently other means have to be devised. When division into paragraphs is enough and how — if it is not — other means of marking divisions may be used along with paragraphs, we shall consider later (276–285). For the present it is enough to note that in indicating divisions of the chapter or article we have a distinctly logical and an important office for the paragraph to fulfill, and that consequently the paragraphs should shape themselves in the general logical structure.

256. **Inner structure of paragraphs.** — In order to discover the possibilities of structure within paragraphs, let us imagine that we have gathered together all the subject matter for a piece of technical writing and have determined, by the process of logical division of the chapter or the article, just what facts are to go in each paragraph,

but have not *organized* the facts in the separate paragraphs. Obviously this could not actually be done in writing, for when we write, we must place one fact after another in some order and by that very act organize them, at least as much as a string of uniform beads may be said to be "organized." But if we had each fact written on a separate piece of paper, we might have boxes to represent paragraphs and drop into each box the facts we wish in that paragraph. Now it is evident, since ideas cannot be given to readers in confused heaps as they would be in the boxes, that one must be chosen as best to be presented first and that the others should follow in an order determined by some principle. Although the paragraph should be given fundamental unity, as we have seen (255), by the division of the synopsis, it has not coherence or mass until all of the facts in the paragraph are brought into proper relation one to another.

257. In the whole composition (book or short article) and in the chapter, we have found that the main divisions are three: Introduction, Body, and Conclusion. If we examine "Sanitary Engineering," we find that there is generally this same threefold division in the paragraphs. The chief difference is that the divisions are reduced to the lowest terms, in fact the Introduction and the Conclusion may become little more than brief suggestions.

258. In order to see what is meant by the *Introduction* of a paragraph, we have only to compare the outline given in section 254 with the paragraphs for which that outline stands (Appendix, Article XVIII). The subjects treated in the different main divisions are: —

A. Sanitary science.
B. The work of sanitary science.
C. The part of sanitary science considered in this chapter.
D. Civil engineering.
E. Sanitary engineering.

The first words in the corresponding paragraphs are: —

A. "Sanitary science —"
B. "The field of sanitary science —"
C. "In this chapter only a part of the field of sanitary science —"
D. "Civil engineering —"
E. "Sanitary engineering —"

259. The Introduction to the paragraphs here is, in other words, a Title, generally expressed as the subject of the first sentence. If paragraphs have no definite unity, if they are but bits of the chapter or whole composition chopped off, they cannot be given such introductory word or group of words; but if the paragraphs have definite subjects, they can easily be so arranged that the first sentence will at the start suggest that subject. Some writers thus introduce their paragraphs frankly, baldly we may say; but to many this gives a structural monotony, which is offensive. In many cases it is possible to give variety by suggesting the subject somewhere within the limits of the first sentence, instead of formally stating it. Other writers go still farther in the formality of the construction of paragraphs and start with a "topical sentence" which gives briefly the substance of the paragraph, which the remaining sentences only elaborate. The paragraphs in the first article in "Sanitary Engineering" are of this sort, each starting out with a topical sentence. Of a book in which the paragraphs are constructed with Introductions, it is possible to get a complete topical outline by reading the first words of each paragraph. No one would wish, except perhaps out of curiosity, to gather together an outline of a whole piece of writing by gleaning the introductory words of the paragraphs, and most find it distinctly monotonous to read a long series of paragraphs each of which is the expansion of a topical sentence; but the reader gets a much more in-

telligent idea as he reads if each paragraph has a definite subject and the subject is at least suggested at the start.

260. In a similar way the *Conclusion* is expressed in the last sentence or the last words of the paragraph. The paragraphs in the article to which we have been referring end as follows: —

A. "sanitary science has for its aim the preservation and protection of the health of the community under the combined action of physicians, engineers, and the civil authorities."

B. "It invokes the science of the biologist and chemist, the experience of the physician, the constructive talent of the engineer, and the authority of the legislature in order to preserve and protect the health of the community."

C. "This chapter aims to briefly explain some of these subjects, in order that the student may obtain a broad view of the whole field, and that the engineer may be better able to effectively coöperate with the other professions in advancing the sanitary condition of the community."

D. "The engineer, according to the definition of Telford, utilizes the materials and forces of nature for the benefit of man, but to this should be added that in so doing he aims to secure the least possible cost of construction and maintenance."

E. "A pure and abundant water supply, and an efficient system of sewerage, have been universally found to promote cleanliness and prevent the spread of disease; to construct these in an economical manner is the main work of the sanitary engineer."

261. The Conclusion may be the final fact in the logical development of the subject of the paragraph or the special thought which the writer wishes to make emphatic in that particular paragraph; it may summarize the substance of the paragraph, mark the advance in the development of the whole subject made in the paragraph, or give to the subject the turn which will lead the reader to the

subjects of the following paragraphs. Just as a topical outline of a methodically written piece of exposition may be made up from the first words of each paragraph, so a summary of the information given about those topics might be obtained by reading the last sentence of each paragraph. By reading the beginning and the ending of each paragraph, then, one would get a good summary of the whole substance. Of course one unfamiliar with the subject could not limit his reading to these Introductions and Conclusions and get as much as if he read the whole subject; but it is possible for one who has carefully read the whole subject to review it easily and helpfully in this way. This suggests how much may be done to help the reader by such an organization of the paragraphs.

262. Between the Introduction and the Conclusion comes the *Body*, the logical development of ideas by which the writer leads the reader from the paragraph "Title" to the special point which he wishes to develop in that paragraph. The development here is obviously much briefer and less complicated than that in longer units, but it must be built up with the same care and on the same principles.

263. **Paragraphs of force and paragraphs of relationship.** — Most of the paragraphs in exposition are, if the subjects are properly expressed, of the structurally complete type which has just been explained (256–262). But if all the paragraphs are of this type, the style tends to become heavy and monotonous. It is not necessary to split paragraphs into fragments, however, merely for the sake of variety, because there are two other types which have important uses which are enough different to break up the monotony: the paragraph of force and the paragraph of relationship.

264. In the *paragraph of force* the intent is not to carry through a complete logical development; rather it is to

bring out one idea emphatically. With many writers this sort of paragraph is used very largely, a number of successive sentences being indented, each as a separate paragraph. This not only tends to break down the distinction between the sentence and the paragraph (which is a very important distinction), but if carried to excess, makes a tiresome, "choppy" style; and above all it defeats its very purpose, for, as in the case of any other kind of emphasis, if each idea is stressed, the result is that no idea gets particular emphasis. In the paragraph of force the structure is condensed, we might say, so that there is nothing left but the Introduction and the Conclusion, expressed in a single sentence or it may be in two sentences. The proper presentation of almost any technical subject leads to the organization of most of the ideas into groups which are adequately expressed only by structurally complete paragraphs; but if the idea is such that the reader can get it in the condensed form, and if it is important enough to warrant attracting his attention to it specially, the paragraph of force is amply justified (Article X, paragraphs giving "claims").

265. *Paragraphs of relationship* are similar to paragraphs of force but serve a somewhat different object. When the grouping of the ideas is a little difficult for the reader to grasp, if it is important that he should not miss the logical relationships, it is possible to introduce a paragraph to express simply the relation of ideas. This type of paragraph may serve to indicate the relation of the preceding to the following paragraph, in which case it is often called "transitional"; it may serve to sum up or check off the progress made in preceding paragraphs; or it may serve to bind together several paragraphs which are to follow. Such paragraphs may not present any "facts" (28 (3)), they may give simply ideas of relationship; in comparison with completely constructed para-

graphs they may be said to consist wholly of Introduction or of Conclusion (Article XXI, paragraph 2).

266. **Meaning and value of properly constructed paragraphs.** — It is quite evident that paragraphs may be constructed on an entirely different principle from that of wire nail cutting. Most writers know this perfectly well, but many do not fully appreciate the value of properly constructed paragraphs. Instead of being shaped in the process of writing the final draft, they should, both as divisions of the larger whole and as separate units, grow out of the structure of the whole subject and take shape in the original planning. How that may best be done we shall consider in Chapter XII (326); but it should be recognized here that, after the facts to be presented have been gathered and have been sufficiently tested for accuracy and completeness and have been arranged in the best order, the most important thing which the writer has to do in order to give his ideas a form of expression which is effective for the reader, is to construct his paragraphs. The engineer will find it serviceable to analyze some of the paragraphs in his technical reading, or in the Appendix of this book, to decide in each case whether or not the paragraphs are effectively organized.

Sentences

267. **The ultimate unit of verbal expression.** — Of the various divisions of a long treatise, — volumes, parts, chapters, sections or articles, and paragraphs, — each is a unit itself, and is made up of smaller divisions which themselves are units. The divisions of paragraphs are sentences, and in exposition the sentences ought to grow out of the paragraph as a whole just as certainly as paragraphs should grow out of the larger whole. Like paragraphs also, sentences should have unity and logical

structure of their own; but in the process of more and more minute division, sentences are the ultimate unit. They, too, are made up of parts, but these parts have not in themselves unity and completeness; they should give a distinct idea of fragmentariness and demand completion in the rest of the sentence. Completeness and fragmentariness are here as elsewhere, be it understood, relative terms. For example, "There are hilly places on this road," is by itself a complete idea; but if the thought to be expressed is, "There are hilly places on this road which have not been properly graded," the first part is incomplete because in the connection in which it belongs it does not give a whole idea. And it does not help matters to make the second part a grammatically complete sentence instead of a relative clause: "There are hilly places on this road. They have not been properly graded." Sentences are, therefore, when properly constructed, units which cannot be split up, in the circumstances in which they are used, without reducing the ideas to fragments.

268. The relation of sentences to the paragraph. — The way in which sentences are related to the paragraph of which they form a part may be brought out strikingly by making a synopsis of the first and second paragraphs of Article XIX of the Appendix (Article 19 in "Sanitary Engineering"), in which the paragraphs are indicated by the divisions A. and B. I, the division into sentences by the horizontal lines.

SURFACE WATERS

A. (General characteristics of surface waters.)
- I. Surface waters
  - 1. include:
    - *a.* swamps,
    - *b.* brooks,

c. rivers,
d. lakes,
2. differ, in these four cases, greatly in regard to their characteristics.

II. (The general characteristics are:)
1. swamp water is liable to be heavily charged with vegetable matter,
2. brooks and rivers, by their flow, cause continuous improvement,
3. lake water is the purest surface water.

III. This improvement in quality is effected in two ways:
1. by settling or sedimentation, which removes the suspended matter,
2. by aëration or contact with the air, whereby oxygen is supplied to decompose and destroy both the suspended and the dissolved organic matter.

B. (Special characteristics of each of kinds of surface waters.)
I. Swamp water
1. usually has
a. a high proportion of vegetable matter in the total solids,
b. a high proportion of albuminoid ammonia.

---

2. In boggy and peaty regions
a. is of a brown color,
b. contains vegetable matter fortunately in a permanent state which resists further decomposition so that these waters are
y. sometimes noted for their keeping qualities and
z. well adapted to be taken on long sea voyages.

---

3. When used for a public water supply
a. is aërated by the pumping and flow so as to cause the organic matter to decompose,
b. must, therefore, be filtered.

4. At Long Branch, N.J., Norfolk, Va., and other cities
   a. is used without unpleasant results,
   b. is convenient for washing because of its softness,
   c. is not so suitable for drinking as brook or river water, when either of the latter may be had.

Each sentence, it will be seen, marks an important synoptic division of the paragraph.

269. Simple, compound, and complex sentences. — Sentences may be constructed in various ways, but there are three general classes: (1) those which express a single idea by means of one subject and one predicate; (2) those which express two or more coördinate ideas, requiring a subject and a predicate, expressed or implied, for each idea; and (3) those which express one main idea modified by one or more subordinate ideas expressed by subordinate clauses. The first sentence in the third paragraph in Article XIX of the Appendix, "Brook water consists of the run-off of the surface, of the drainage of swamps, and of the percolation from meadow and springy land," is a simple sentence. Such sentences offer no structural difficulties, unless there is question whether they express a complete idea in themselves or should be combined with other ideas so as to make up a compound or a complex sentence. The first sentence in the second paragraph (Article XIX), "Swamp water usually has a high proportion of vegetable matter in the total solids, and a high proportion of albuminoid ammonia is also found," is a compound sentence. The following sentence, "In boggy and peaty regions this gives a brown color to the water, but it fortunately happens that the vegetable matter is in a permanent state which resists further decomposition, so that sometimes these waters are noted for their keeping qualities and are well adapted to being

taken on long sea voyages," consists of a simple sentence compounded (by " but ") with a complex sentence which contains a relative clause " which resists further decomposition " modifying " state " and a compound result clause, " so that sometimes these waters are noted for their keeping qualities *and* are well adapted to being taken on long sea voyages." Compound, complex, and compound-complex sentences offer many difficult problems of grammatical structure, but with those we are not concerned here. There are two ways in which they express logical structure, however, to each of which we need to give brief attention.

270. In the first place, it is not always easy to distinguish between coördinate and subordinate relations in constructing sentences; but in as far as the sentence is expressing logical relationships which have been adequately worked out in synoptic form, the question is already settled in the synopsis. For example, of the sentences just given in synoptic form (268), divisions 1 and 2 in the first sentence, 1, 2, and 3 in the second sentence, and 1 and 2 in the third sentence are all coördinate; while of the four facts about water in boggy and peaty regions given in the fifth sentence, *a* and *b* are coördinate while *y* and *z* are subordinate to *b*. In other words, to express logically coördinate ideas within a sentence, the elements should be joined coördinately; to express ideas logically subordinate to other ideas, subordinate clauses should be used. In the second place, the exact nature of the relation between the different elements of the sentence should be expressed. Since the form of the synopsis indicates but one kind of coördination and one kind of subordination, the consideration of the means of expressing the exact relationship between the elements of a sentence carries us beyond our present problem of expressing the synoptic structure in the final form to

sentence structure which we shall consider later (306). The coördination or subordination of ideas in sentences seems to many a minor matter, but if it is done exactly, it is an important help to the reader.

Punctuation Marks Useful in Indicating Structure

271. Punctuation marks serve different uses, but there is no occasion here to consider any except that of indicating the *grouping* of words within single sentences. In expressing logical relationships within sentences, punctuation marks may indicate series the members of which are of equal value, series the members of which are of unequal value, parentheses, and ellipses.

272. **Series the members of which are of equal value.** — To indicate a series of coördinate ideas where punctuation marks are required, we should use the same mark to cut off each of the different members, just as the miles along a railroad are cut off by similar markers. If the series is made up of single words, phrases, or simple clauses, the comma (,) should be employed. If the series is made up of the parts of a compound sentence, that is to say, of parts each of which might stand as a sentence, the semicolon (;) may well be used instead of the comma. If the series is made up of parts which for any reason are themselves subdivided by commas, the semicolon should be used to mark the larger divisions.

Surface waters include those of swamps, brooks, rivers, and lakes.

In summer the flow becomes normal and the highest degree of purity obtains; in autumn the flow is a minimum and liability to polution is greater than in the summer.

Swamp water has been used at Long Branch, N.J., Norfolk, Va., and other cities without unpleasant results; its softness renders it convenient for washing, but brook or river water is always to be preferred for drinking purposes when it can be had.

273. **Series the members of which are of unequal value.** — To indicate that the members of a series are of different values, that is to say, that the series is divided into parts, some or all of which are subdivided, more than one kind of mark must be used, just as marks of different lengths are used to indicate feet, inches, and fractions of an inch on a yardstick. There must be a punctuation mark of lesser value, a mark of greater value, and often a third mark of greatest value. For this purpose the comma is employed as the mark of lesser value, the semicolon as the mark of next greater value, and the colon (:) as the mark of greatest value.

> In Europe this subject has received much attention, and the matter that may be thrown into rivers is regulated by law; in this country some states have also made enactments which in time will no doubt be perfected and enforced.
>
> This improvement in quality is effected in two ways: first, by settling or sedimentation, which removes suspended matter; and second, by aëration or contact with the air, whereby oxygen is supplied to decompose and destroy both the suspended and the dissolved organic matter.

274. **Parentheses.** — A parenthesis is any word or group of words which distinctly interrupts the natural development of the ideas in a sentence, or which comes into the sentence at a place which breaks up the natural order of the words. To indicate parentheses a pair of marks of equal value should always be used, unless the parenthesis comes at the beginning or the end of the sentence, in which case but one mark is needed. Nouns in apposition, adverbial modifiers out of grammatical position, vocatives, and explanatory clauses are, according to the common habits of the language, cut off from the rest of the sentence by commas; but this use of punctuation marks is seldom important in indicating logical structure, except perhaps where the second of a

pair of words connected by " or " is cut off by commas to indicate that it is simply another word for the idea expressed by the first word of the pair.

A riddle, or sieve, is used to sift on the sand.

Words or groups of words which definitely interrupt the development of the idea in a sentence may be cut off by commas; but since the comma is used for so many purposes, confusion may arise, in which case the words are better cut off by curved marks of parenthesis ( ), or by a pair of dashes (— —). Usage does not distinguish between these two marks except that if the parenthetical expression comes at the end of the sentence, it is cut off by a dash, never by a curved mark. The curved marks are also used to inclose explanatory matter which may be entirely omitted by the reader.

In case the person making the survey also balances it, as should always be the case when possible, the second method should be followed.

Focus the telescope on a distant point (theoretically the point should be infinitely distant, as a star) and measure the distance from the center of the objective to the plane of the wires.

By adopting these precautions and determining a factor for each of several average conditions, — say for each of the four seasons, — a degree of precision of one in two thousand to one in five thousand may be obtained with the stadia.

Potassium permanganate ($K_2Mn_2O_8$) added to water gives a purple color, and if used in sufficient quantity so that the color persists for ten minutes, it causes effective purification.

275. **Ellipsis.** — When in a sentence some little of the idea is repeated without the repetition of all the words, the fact and the place of the omission may be and often needs to be marked by the insertion of a comma.[1]

[1] All that has been attempted here in considering the use of punctuation marks is to suggest the important ways in which they may indicate logical structure. For an adequate statement of their uses it is necessary to consult a treatise on punctuation.

The vent tube is usually about three inches in diameter; the fresh-air inlet pipe, four or five inches.

Other Means of Indicating Structural Relationship

276. We have considered so far chapters, paragraphs, sentences, and punctuation marks as means of indicating structural relationships. One writer may use these means intelligently in expressing his ideas, another may use them blindly, but the habits of writing are such that no one ignores them. There are, in addition, three other common ways of indicating relationships which may or may not be used by a writer: (1) the introduction of formally marked divisions of books more inclusive than chapters, or of similar divisions of chapters more inclusive than paragraphs; (2) the use of words, phrases, sentences, or paragraphs to indicating groupings not marked by paragraphs or sentences; and (3) the use of differences in typography.

277. **Divisions of books and of chapters.** — Books may be divided into "parts" and chapters into "sections" or "articles." Such divisions should not be made unless they indicate important groupings of the smaller units; but if they find justification in the structure of the subject, they are of real assistance to the reader. Divisions of this sort make it easier to discover and keep in mind the plan of the treatment, and they break up the otherwise long series of chapters or paragraphs and give all the benefits (65, 66) of such grouping.

278. **Verbal indication of structure.** — A series of coördinate divisions (chapters, paragraphs, or sentences) may be bound together into a larger group by the use of paragraphs, phrases, or words which formally explain or suggest such grouping. We have already seen (240–245) how the writer of "Sanitary Engineering" has indicated that while Chapter I is the Introduction, Chapters II,

III, IV, V, and VI all together form the Body, though each of the chapters in the Body is, in as far as it is marked simply as a chapter, independent from the others and coördinate with Chapter I. We have also seen (247–250) that in Chapter I, "Articles" III–XIV are grouped together as modern sanitary science, as distinct from "Article" II which gives "historical notes," by the suggestion of the Titles and by the formal explanation at the end of "Article" II: "The progress that has been made since that time will be recorded in the following pages under the several subdivisions of the subject." In Article XIX of the Appendix we have six paragraphs, but the second, third, fourth, and fifth belong in a group by themselves distinct from the first and from the last; and that fact is not indicated by any division more inclusive than the paragraph, but is suggested by means of words. In the first paragraph, surface waters are explained as including "those of swamps, brooks, rivers, and lakes"; and the following four paragraphs which give the characteristics of these waters begin: (1) "Swamp water," (2) "Brook water," (3) "A river," (4) "Lakes." As we read these paragraphs we know that the explanation of the characteristics of surface waters which begins with the paragraph on "Swamp waters" is not completed till we have finished the paragraph on "Lakes." In a similar way sentences which together form a group within a paragraph may be sufficiently joined by suggestive or explanatory words. Such sentences might be combined to form a single compound sentence, but sentences of such length are not in good use in English writings of the present times.

There are three common patterns of leveling rods. The Philadelphia rod is so graduated as to be easily read at ordinary distances by the leveler. The New York rod has a target provided with a vernier, usually placed below the center of the target. The Boston rod has a target fixed to the rod.

279. The different groupings of the ideas in a piece of technical writing should be indicated as fully as possible by the divisions into chapters, paragraphs, and sentences; but where these divisions are insufficient, it is always possible to explain further grouping by the choice of proper suggestive words or at most by the addition of a word, phrase, sentence, or paragraph clearly indicating the grouping.

280. **Typographical indications of structure.** — When a book or a short article is printed, the relationship of ideas may be indicated in various ways by differences in typography. These differences mark distinctions within a single chapter or within the whole article if it is not divided into chapters. They are of two sorts, headings and differences of type in the text itself.

281. There are three kinds of *headings* in common use: centered headings, side headings, and marginal headings. Centered headings are used to mark important main divisions and are printed all capital letters or "bold-faced" letters (Article XXIV). Two or more grades of such headings are sometimes used, the difference being indicated by size or style of type or by the use of capitals and small capitals in one case, and capitals and lower case (small) letters in the other. In general, however, such complications in centered headings only confuse the reader. Instead of attempting to do so much by centered headings, it is always possible to place a brief outline at the beginning of the chapter. Side headings are set to the left, indented as for paragraphs. For this purpose bold-faced type, capitals and small capitals, or italic capitals and lower case letters are used. Different gradations of side headings are not used, since such headings are simply titles for the paragraphs or groups of paragraphs. Marginal headings consist of titles or brief explanatory suggestions printed in the margin at the left or right, or at

the left just within the limits of the text but with white space enough about to set them off clearly. If the title is set out in the margin, it is generally printed in the same style type as the text, only of smaller size (" point "); if it is set into the text, it may be of smaller point or bold-faced. Such headings are often very helpful to the reader, for they are easily picked up by a glance at the page, and they may serve to call special attention to important points or to divisions of the subject which may include several paragraphs. Unfortunately the fact that the letters of headings in the margin wear much more rapidly on the press than letters in solid text, and the fact that both kinds of marginal headings are expensive in these days of typesetting by linotype or monotype process are disadvantages which the author and the publisher have to consider.

282. *Differences in type within the text* itself are used chiefly for two purposes: to indicate differences of authorship, and to indicate different degrees of emphasis. Where a long quotation is introduced or where many quotations are used for purposes of illustration, it is common to print the quotations in different type, usually of the same style as the text but of smaller point. This sets the quotations out distinctly and at the same time avoids the necessity of using quotation marks which are unnecessary and are often confusing, especially if there are quotations within quotations.

283. The introductory words of a paragraph (259) may be typographically marked to call attention to the subject of the paragraph, or any word or words in the paragraph may be similarly brought out in order to call the reader's attention to the gist or the essential point. For these purposes small capitals are sometimes used, but more commonly bold-faced type or italic lower case letters. Between the last two the difference is mainly

this: the italic in the judgment of most people disfigures the text less, especially if many words are thus marked; on the other hand, bold-faced is less ambiguous if italic is used to mark foreign words.

284. In the last place, a paragraph or a small number of paragraphs may be printed in type of smaller point to indicate that the subject matter so marked is of less importance or may be omitted by those readers who do not care to take up the fuller treatment.

285. In general, it may be said that the use of typographical distinctions should be adopted sparingly. The nearer a piece of writing approaches to "literature" in character, the more objectionable any use of special type becomes. In general technical writing, however, a moderate use, and in books for serious study or for reference, a more generous use, of typographical distinctions is a real help to the reader. The writer does not need to master the practice of typography, that is a business of itself; but he should know enough of the use of type to be able to talk intelligently with his publisher, and he should keep in mind the general possibilities in shaping his writing.

THE SECOND PROBLEM

Other Rhetorical Principles to be observed in the Final Writing

Choice of words, §§ **287–299**.
Order of words, §§ **300–305**.
Sentence structure, § **306**.
Correct use and good use, § **307**.
Determination of length of divisions, §§ **308–312**.
Distinction between "literature" and scientific writing, § **313**.

286. The most important rhetorical principles (those of "unity," "coherence," and "mass") the writer must observe if he builds up the proper logical structure. With

those principles we were concerned in the first ten chapters. In the first part of this chapter we have considered no new rhetorical principles; we have simply examined the ways in which the structure which the writer has built up in his head or on paper in the form of a synopsis may be expressed for the reader. There are, however, other rhetorical principles, mainly those concerned in the choice of words, the order of words, the structure of sentences, and the determination of the length of sentences and paragraphs, which do not need to be considered till the writing of the final form. It is with them that we shall be concerned in the remainder of this chapter.[1]

Choice of Words

287. **Technical terms.** — The special peculiarity of the vocabulary of technical writings is, obviously, the preponderance of "technical terms." Exact sciences cannot use common or popular terms, first, because many objects and conceptions with which science deals do not enter into common experience and consequently have no common name; and, second, because popular terms often mean quite different things in different localities or different terms in different places mean the same thing. For example, "robin" in England means a small singing bird like a warbler; in the United States it means a larger bird of the thrush family; and in Australia and in India the name is given to still other varieties. Or, again, the definite and well-known variety of American woodpeckers, technically called *Colaptes auratus*, is popularly known as "flicker," "golden-winged woodpecker," "yellow-hammer," "yucker,"

[1] Since these are matters of general composition, they will be treated here very briefly, on the assumption that all that is needed is to call attention to them. The engineer who wishes further instruction at any point should seek it in some standard rhetoric.

"highholder," "pigeon woodpecker," and by various other names in different localities. By a "technical term" we mean a word used to express a definite idea in the vocabulary of some special "technic," that is to say, some special art, science, profession, or trade. Such terms, representing the opposite extreme from the words which are specially characteristic of poetry, have less suggestiveness, less emotional force, less "connotation" than general or popular terms. They are definite and exact in their logical meaning, their "denotation."

288. An important part of the increase in the vocabulary of languages at the present time is due to the continual *addition of technical terms.* This is necessary in the case of any technic which is growing, and in such cases as the making out of specification for a patent (Article X) the individual writer often has to originate technical terms. A very few of these, like "gas," are pure inventions. Others are the names of men honored for scientific work, such as "joule," or the name of the one who invented that for which the term stands, as "macadam." Many terms are brought in from foreign lands with the object or idea for which they stand, as "garage" or "hinterland"; or are coined as the need comes up from Latin or Greek, as "torque" "dynamo" or "monoplane." Still others are formed from words previously in the language: by spontaneous change, as "to skid"; by analogy, as "jacket"; or by composition, as "lightning arrester." It is always desirable that something in the origin or previous meaning of the word should make its technical use reasonable, as in the case cited above, but it is also desirable that the word should not bring with it from general or popular use associations of ideas which make it ambiguous. It is on the ground of avoiding popular association of ideas that a foreign word such as "garage" (for automobiles) or "hangar" (for flying machines) is preferable to one of

native origin such as "car barn," which already is associated with trolley cars. Whatever the origin or the justification for the use of the term, however, when it is once accepted generally by those who are of the special technic, it becomes a technical term and should be used by anyone speaking or writing on that subject.

289. In technical writing, technical terms should be used as freely as the subject permits, but it should be remembered that while a technical term has for those familiar with it an exact and definite meaning, it has no meaning at all or a meaning which is incomplete and inexact for those to whom it has not been defined. Consequently the writer *needs to define every technical term* which he does not feel safe in assuming the reader already knows in its exact usage. The success of a writer on a technical subject depends largely upon the skill he shows in deciding what terms he may use without definition, and in defining all others.

290. If a term needs definition, it generally should be *defined the first time it is used.* Often a writer uses a term several times and then, when first he realizes that it needs definition, explains its exact meaning. Either the explanation of the term is not required, or it is needed the first time it is used. When it is not desirable to define a term the first time the thing it stands for needs to be mentioned, it is sometimes possible to indicate the object by a general term which will convey all the meaning needed at that point, and to leave the introduction of the technical term till later, when the exact definition may be given. In Article I, it has already been noted, the author first speaks of a "pointer" (simply something to mark a position on a scale) and later explains that "the pointer is the zero mark of a vernier." There are a few instances where technical terms may be used at first without definition, even when an exact definition must be added later.

Such cases arise when the term has a loose general meaning which will serve at the start and perhaps is all that the reader can appreciate till the subject has been in part developed. In an elementary treatise on physics, for example, " work " may be used without definition at first, and then, when the reader has gained more exact ideas, the term as it is used in mechanics may be fully explained. In all cases, however, it is important that the writer should see to it that his reader gets both the technical term and its exact meaning where he will find them most helpful.

291. Although it is always necessary to define terms which are new to the reader, it should be borne in mind that such explanatory matter is a *digression* which may distract the reader's attention from the main development of the subject. Consequently definitions of terms should always be omitted if not needed, simplified by being inserted at a point where the reader can most readily comprehend them or by being fortified by an illustration, or they should be removed from the Body and placed in the Introduction. The grounds for deciding where to insert such definitions have already been discussed (89–93, 119).

292. Questions frequently arise as to the need of *defining terms which do not belong exclusively to the special subject* which the writer is treating. On general principles such terms should not be defined; or rather they should not be used unless they are such as any intelligent reader of this particular subject should know. If they are simple and common technical terms, they are properly defined in any unabridged dictionary, and it is better for the reader who does not happen to know them to look up their meaning than for the writer to lumber up his explanation with such definitions. If they belong to the general subject with which the writer is dealing, but should have been learned by the reader before he turns to the special subject, it is still the reader's business, if

he has forgotten their meaning, to look them up. Yet (and this is an important consideration) it is well known that readers seldom do look up things which they ought to know but do not, and if an understanding of the subject depends upon a clear knowledge of the meaning of any term, it is the part of wisdom for the writer to define it. This should be done with extreme brevity, in a parenthesis, in a footnote, or by an illustration if possible, so that while the reader who does not know gets the information, the reader who knows is not unnecessarily burdened (191). In Article VII, as we have already noted, we have an example of the introduction of brief definitions of terms which the reader should already know but must have in mind in order to understand the following explanations. The term "table" in its general mathematical sense, anyone ought to know; the terms "argument," "function," "tabular interval," and "tabular difference," anyone who has got far enough in the use of logarithm tables to wish to learn how to interpolate ought to know. Yet the explanation which follows would have no real meaning if the reader had not the meaning of the terms actually in mind. "Table" is covered by the sample table given. The argument and the function in this table are labeled and referred to in the text. "Tabular difference" and "tabular interval," which may not have been met by the reader, or may not have been accurately defined to him, are briefly but fully defined in the text.

293. **Undesirable words.** — Aside from nontechnical words used where technical terms should be employed, there are several classes of words which should be avoided in technical writing. Any word which is ambiguous or which for any reason will be ambiguous to the particular readers addressed, should be avoided in technical as in any other form of writing. Current slang is particularly objectionable, not only because such words have a flippant

connotation out of place in serious writing, but because they generally have no exact meaning at all. Slang expressions when first used are known only to a few; as they get into general use, their meaning usually changes rapidly, even coming to contradict the original sense; if they become popular, they are used so freely that they have no definite meaning at all ; and soon they may drop out of use entirely. In every way slang is unfit for use in technical writing. Similarly any word or expression which comes to be a pet expression with a writer is generally one for him to avoid because its use on all sorts of occasions necessarily leads to its having no exact meaning in any case. On the other hand, bookish words are to be avoided, that is to say, words which the writer knows only as words in books and which he introduces because he thinks they sound well. Such expressions are seldom used with real and exact meaning.

294. There is one class of technical terms employed freely by some which need more attention than is given to them by any but especially careful writers. They are what may be called *perverted words*. In the development of technical terms, words are sometimes strained out of their original meaning in a way to introduce needless confusion. Some become fixed in technical usage so that although they may be regretted, they may not be condemned ; but a writer should always be careful that he does not needlessly use terms in perverted senses. For example, the word " duty " as it is used in mechanics to express the efficiency of an engine in terms of the number of foot pounds of work done per bushel or per hundredweight of fuel consumed is, even in its exact technical sense, unfortunately chosen ; but when it is loosely used for any demand put upon an engine or any other device, it needlessly confuses material efficiency with personal responsibility. In a similar way " theory " is used in physics in

the sense of "principles," as in the case of the "theory of the vernier," when all that the term covers is a statement of observable facts. This introduces confusion between such a use of the term and the more justifiable use of "theory" for ideas which have their origin in the mind as distinct from facts of observation or of practice,—a distinction which it is important to keep clear. The term "horizon," which the geologist uses for "the strata all over the earth formed at the same time" and consequently for the geologic position of a stratum, is carelessly used by some for "stratum" or "bed." As scientific study has become more exact, technical terms are getting to be more carefully chosen and more rigidly used, as we see in mathematics, chemistry, and physics. Such work must be done by eminent authority, usually nowadays through some representative organization, but the individual writer should see to it that he does not himself introduce confusion.

295. *Unnecessary words,* it is needless to repeat, should be omitted; the difficulty lies in determining what words are unnecessary and how they may be omitted. For many it is extremely difficult to acquire this phase of the art of "boiling down." If the structure of the writing is carefully made out, much may be done at the start by the exclusion of all unnecessary ideas and by the brief statement of the ideas which, being subordinate, need not be given full expression. In writing the final draft, many words may be saved by guarding against sentence structure which is faulty or which entails the use of needless circumlocutions. In speaking we often get well into a sentence before we have considered how we can end it; consequently we are compelled to use extra words for lack of proper sentence planning. There is no such excuse for verbosity in writing. No part of a sentence in its final form should be written till the whole has been framed; and the simplest construction which will express the facts

should be chosen. Circumlocutions are sometimes serviceable (303), but such expressions, as the common, "it was seen," "it could be seen," or "it was seen by me," for "I saw," are simply evidence of the writer's lack of mastery of the art of concise expression. The proper construction of sentences we shall take up later (306), but words are frequently used unnecessarily in three other ways which may be considered as questions of choice of words.

296. In the first place, when a word or a group of words is repeated, it is always open to suspicion. It is a well-known psychological fact that when we have once used a word its chances of coming again to mind, if soon after we wish to express a somewhat similar idea, are much greater than those of a word which has not been used; consequently words get repeated, especially in the language of lazy thinkers, many times, when the ideas for which they stand in the different instances are different. In such cases each use of the word should be tested to see if it could not be replaced by another and a more exact word. In some cases such substitution is impossible. If we must speak of the same thing five or six times, we may have to use a single word that number of times. It is always better to repeat a word than to refer to it in a way that obscures the meaning for the reader, or to use another word which does not express the idea so exactly. Generally, however, such repetition of a word may be avoided by a careful construction of the sentences which will make some of the uses unnecessary; and when that is possible, it should always be done.

These *posts* are of a length sufficient to embed them into the ground with the top projecting five or six inches above and the bottom below the frost line to prevent the *posts* from (their) being moved by the frost in winter. Granite *posts* are (Granite is) used to some extent, but lately a new design, consisting of an iron *post*, is taking its place.

297. In the second place, many words creep in which are not strictly required by the structure of the sentence. They may be idiomatic, and the English language in particular tends to introduce them in idiomatic expression. The adverb " up " is a great offender. From its use with verbs to add the idea " completely," as in the expression, " to eat up the apple," it comes in certain technical uses to be tacked on to about every verb : " to level up," " to slick up," " to varnish up," "to smooth up," " to ram up," etc. Conciseness is served when such words are omitted every time that they do not add a real and important idea.

298. In the last place the number of words is often greater than need be because the separate word is not so chosen that it does its full service. In naming an object we do not always need to use a noun and an adjective giving the essential quality, for the language may have one noun which includes both. We do not need to say " black man " for there is the word "negro." So verbs may express, not only a general action or state, but specific actions or states. There is not only the verb " to say," but the verbs " to whisper," "to shout," " to mutter," " to mumble," "to roar," "to call out" and many more. If one of these specific verbs expresses exactly the idea, it is more economical than to use the verb "to say" with a modifier of one or of many words. It is not always better to use one word instead of two or more, but the presumption is in favor of the single word, and when the number is increased just because the writer is thinking lazily or is not using all the language possibilities at his command, it is certainly a defect. It is a good rule to pack as much meaning as possible into the fundamental elements of the sentence (subject, verb, and complement), and then to choose, where necessary, single-word modifiers if possible. The piling up of modifiers and especially the frequent use of

secondary modifiers (modifiers of modifiers) is to be avoided. The intensifier "very" is much overworked, the result being, not only to add unnecessary words, but also to weaken the force of the intensifier from overuse. Other words of this sort may be still less effective. "Quite" in the spoken language has two distinct meanings: one, "entirely," and the other, "passably." The distinction in meaning is generally clear enough in speaking because of the inflection of the voice, but in writing the distinction is lost. Consequently it is the safer course never to use "quite" in writing except where it is clear to the reader that "entirely" is meant. Each writer may have his peculiar weak, colorless words, but whatever they may be, they should be omitted or replaced by other words which express the ideas more effectively.

299. **Proper association of words.** — In choosing words it should be remembered that a single word is not right or wrong by itself. Whether or not it is the best that can be found depends largely upon the other words with which it is used.

No such sensation is *witnessed* (felt).
In order to *explain* (understand) this it is necessary to know the principle.
As is *seen by* Figure I (shown by, or seen in Figure I).
The failure of this bridge has *placed* this question *astir* (stirred *up interest in*).

Order of Words

300. In determining the order of words in sentences the writer should consider principles of clearness, of variety, and of emphasis. In highly inflected languages, that is to say, in languages where the relations of the different words in the sentence are largely indicated by differences in the form of the word, the order is determined mainly on

principles of variety and of emphasis. For example, in the Latin sentence, *Brutus Cæsarem interfecit,* any one of the six possible combinations of the words would be clear ; the order just given would probably be chosen because of the general habit of the language, but it might be changed to give variety and especially to change the emphasis. English, however, has not such free possibilities of order. We can say only, " Brutus killed Cæsar," for no other order of words would give the meaning of the Latin sentence. The whole problem of order of words in English cannot be considered here, but a few principles should be noted.

301. *Clearness* requires mainly the observation of two rules. First, in the declarative sentence the fundamental elements should come in the following order : subject, verb, complement, if any. The observation of this rule, the variations in other than declarative sentences, and the few special cases in declarative sentences where variation is possible offer no difficulties to anyone to whom English is a native language. Second, modifiers usually should immediately precede or follow the word modified. Where the position of the modifier in relation to the word modified is fixed by the habits of the language no difficulties arise for the native. Modifiers of the verb (simple adverbs or clauses) may be introduced in different parts of the sentence. In these cases also there are no serious difficulties except when the modifier might grammatically limit or qualify more than one word in the sentence : under such circumstances the modifier should be so inserted that the structure of the sentence as the writer intends it is perfectly clear. For example, in the sentence, " Darwin suggested theories," the word "only" may be introduced to modify any one of the three words ; consequently it should be placed so that it is perfectly clear which word the writer intends to modify.

Only *Darwin* suggested theories.
Darwin only *suggested* theories.
Darwin suggested only *theories*.

So in general in English we should recognize that the order of words must first of all make the construction of the sentence, and therefore the meaning of the writer, perfectly clear.

302. Fortunately, however, without destroying clearness, certain modifiers may be inserted in different places in the sentence, making possible variation in *the order of words*. For example, in the sentence, "Lincoln was supported there," the word "generally" may be added before or after any word in the sentence without changing the sense. If it were not for these and a few other possibilities of variety in the order of words in sentences, English would be unbearably monotonous, and every writer should see to it that he does not fall into the habit of constructing successive sentences with wearisome similarity of order.

303. It is seldom necessary, however, in technical writing to vary the order of words for variety's sake alone, because the different sentences, if properly constructed, will be put together in different orders for the purpose of bringing out the right shade of *emphasis*. There are certain words in sentences which under ordinary conditions receive no emphasis: the proclitics, like the article "a," which are pronounced as if they were a part of the following word; and the enclitics, like the word "to" in such a sentence as, "He does not have to," which are pronounced as if they were a part of the preceding word. All other words have naturally some accent, some emphasis; and by a proper construction of the sentence the emphasis of any one may be increased. This is largely a question of order of words. In speaking the proclitics and the enclitics may be émphasized by

voice stress, and such emphasis is indicated in print by italic letters, in writing by underscoring. The subject of the sentence, the verb, and modifiers which have fixed position must also, in the sentences in which there are other words which might take the emphasis, be underscored or brought to special attention by the use of some circumlocution.

The bridge was swept away.
It was the bridge which was swept away. (Subject emphasized.)
The bridge was *swept away.* (Verb emphasized.)
The bridge which was swept away was the longer one. (Modifier of subject emphasized.)

The commoner and more important opportunities for directing emphasis are offered by those words which may be inserted in the sentence at different places. There are three positions in the sentence which give special stress to any word or words which may be put there.

304. First, the *beginning* has special emphasis because we expect to find there the important subject of discourse, and because any word in that position comes after a pause or change of subject from the preceding sentence and consequently gets the advantage of the freshly aroused attention of the reader. Secondly, the *end of the sentence* has special emphasis because, on account of the pause following, the words placed there may receive more attention than can be given to those in the middle of a sentence which are immediately followed up by others. Particularly in " periodic " sentences where the sense is not complete till the last word is reached, the weight of emphasis is thrown to the end. Thirdly, *any word out of its natural position* is thereby emphasized, just as anything found in an unexpected place attracts special attention.

305. The emphasis which in speaking may always be given by stress of voice, in writing should be indicated

clearly by the structure of the sentence. In the various ways just mentioned it may be directed to any word in a sentence, as the following illustrates: —

1 2 3 4 5 6 7
The Wachusett Dam is the largest of these.
1
The Wachusett Dam is the largest of these.
2
The largest of these dams is the Wachusett.
3
It is the (Wachusett) Dam which is the largest of these.
4
It *is* the Wachusett Dam which is the largest of these.
5
The Wachusett Dam is *the* largest (of these).
6
Of these (dams) the Wachusett, is the largest.
7
Of these, the Wachusett (Dam) is the largest.

Ideas in sentences are not of one and the same value, and they are not fully expressed, till the emphasis is properly distributed.

Sentence Structure

306. In writing the final draft the engineer expresses his ideas, it may be, for the first time, in complete sentences. And these sentences should always be grammatically constructed. If the writer is not familiar with grammatical principles, he should get a satisfactory text-book and instruct himself at the earliest moment. Above all, he should observe the following points: Each sentence should have a subject and a verb in some finite form and a complement if the verb is one which is not itself complete. The subject and the verb should be in exact agreement. All pronouns which have different case forms should be in the correct case, and should be in proper agreement in gender and number with their antecedent. An adverb, not an adjective, should be used to modify a verb, adjective, or another adverb. The coördi-

nate parts of a sentence should be coördinately expressed. No modifier of any sort should be introduced in a sentence unless there is unmistakably a word for it to modify. Subordinate ideas should be properly subordinated and introduced by the proper conjunction. Gross errors in sentence construction are not common in the work of intelligent writers, at least when the writing has passed through the hands of a reputable publisher, but less noticeable errors slip by, and in the process of composition sentence structure needs careful attention.

Correct Use and Good Use

307. The main object in technical writing is to express one's ideas so that they will be understood; and to many, if the expression is such that the reader gets the ideas accurately, completely, and with no unnecessary expenditure of time and effort, it seems as if there were nothing more to do. They would agree with Martine in "Les Femmes Savantes" that "If you make yourself understood, you are speaking all right." But there is another side. A college teacher who recently got out voluminous notes for one of his classes used a somewhat erratic form of "simplified spelling." There was no difficulty in reading the notes or in getting the meaning, but as one of the students remarked, "The subject was dull itself and with that spelling it was impossible." The engineer needs to remember that over and above presenting his ideas so that they will be understood, he should so express them that no attention will be attracted to the form, for that always means the distracting of attention from the subject matter. Language is nearly as "free as thought," from which it is practically inseparable, but each language has certain fixed habits which make up what is called "correct use," and no intelligent writer addressing intelligent readers should willingly permit himself to vary

from correct use. In many other ways the forms of expression are not so rigidly fixed, and consequently may be determined according to the judgment and good taste of the writer. But in these cases the writer should be guided, not only by his own personal feelings, but by the judgment of those who are recognized commonly as possessing good taste. The questions of "good use" should be settled on their merits with due regard to all the circumstances, but common habits of careful writers should not be ignored. The engineer would not be satisfied with a design which was inaccurate or not executed according to the best practice, he would not be willing to accept the notes of a surveying squad, or the reports of a test that were not presented in proper form, even if the slovenly work was perfectly intelligible. Should he be satisfied with writing which is not correct or according to the practice of good writers?

The Determination of the Length of Paragraphs and of Sentences

308. We have already seen that the sentence, the paragraph, the section, the chapter, etc., are means of indicating to the reader logical divisions of the subject which may be expressed in the synopsis form by indentation and by the use of letters and numbers. If each one of these final form divisions could always stand for logical divisions of the same value, and so represent in all cases divisions of the synopsis marked in a single way, the matter of division in the final form would be very simple. But these logical divisions may differ greatly in length, and common habits do not permit of such variety in the length of the divisions of the final form. In the case of "Sanitary Engineering," for example, of the three main divisions, the Introduction covers about thirty-seven pages; the Body about two hundred pages; and the

Conclusion, a single paragraph of less than half a page. It is evident that these three could not be presented in the final form each as a chapter, though in the synopsis they make up three coördinate divisions. We have already seen (240–243) that the Body is split up into five chapters which nevertheless are held together as a unit by suggestions which make the structure sufficiently clear to the reader. In a similar way divisions of chapters may be made up of a number of paragraphs (251), and divisions of paragraphs made up of a number of sentences (267), which may be so expressed that the reader does not fail to get a realization of the unity of the group of paragraphs or sentences. Consequently the question arises, How much can the writer organize to good advantage into a *single* division, chapter, paragraph, or sentence? In all cases the character of the subject matter, the natural habits of the writer, and the character of the readers addressed should largely determine the answer to this question. Some subjects are by their very nature complicated in such ways that no real unity can be built up unless many details are combined. Anyone writing on such subjects must inevitably use longer chapters, paragraphs, and sentences than would be desirable in presenting a subject in which the separate details are more important. Similarly, some writers cannot form a conception which has any real meaning to them without combining many ideas, while others find it much more natural to treat details by themselves. In the last place, some classes of readers have not the power of grasping large and complicated wholes, while others find that a treatment of a subject which breaks it up into small divisions is jerky, confusing, and ineffective.

309. In determining the length of chapter, section, or paragraph, the essential is to have each division mean something that is logically justifiable as a unit by itself,

and to indicate clearly when two or more of these divisions combine to form a larger whole. A writer is usually safe if he keeps near to the habits common to writers on subjects similar to the one he is treating. There is generally little difficulty in determining the length of chapters. In the case of *paragraphs* the tendency for some time has been in most forms of writing to favor short divisions, and in much technical writing the shortening up has gone so far that paragraphs are little more than single sentences (for example, paragraphs 3, 4, 5 in Article I). In " Sanitary Engineering " there are some two hundred and seventy-five paragraphs on a hundred pages, or between two and one half and three paragraphs to the page. That would seem to be a fair average length.

310. In the case of *sentences*, it is a more difficult matter to determine the length. Habits vary greatly at different periods and in the cases of different writers. In the time of Milton sentences of three hundred words were by no means uncommon. Now many think that sentences are long enough if they average twenty-five words. In an article, " Railroad Rates and Government Regulation," by Lucius Tuttle, published in *The Outlook*, for February 11, 1905, the sentences contain on an average sixty-eight words, varying in length from eight to one hundred sixty-five words. An editorial on the same subject in the same issue is made up of sentences which average thirty words each, the longest containing fifty-three words.

311. The number of words which may be satisfactorily combined into a single sentence depends in part upon the kind of sentence. The simplest way to make up a long sentence is to combine various ideas together by the use of coördinate conjunctions, making a compound sentence. Such are the sentences that the child uses,

and such are those that untrained minds of even the mature favor. Manifestly a compound sentence may be of any length. Theoretically we might string together the ideas of a whole book by the use of coördinate conjunctions and the sentence would still have unity. But it is equally evident that compound sentences fall apart easily at each joint, and must actually fall apart in the mind of the reader before many parts have been joined together. The complex sentence, consisting of a central idea to which are added other ideas which are duly subordinated, is more difficult to construct, less capable of extention, but much more firmly bound together into unity. The periodic sentence, in which the main idea is not given completely till the end is reached, is the most highly developed, the most artificial, but the most solidly constructed. The unity of such a sentence is unmistakable, but if it is loaded with many subordinate ideas, it becomes like a pyramid resting on its apex; the reader's understanding topples over before he gets to the supporting point. Because of the range which usage permits, and the ease with which one who is at all skillful in sentence building may organize together in real unity a great many words, the question of the most satisfactory length of sentences is difficult to settle.

312. A number test (setting the sentence limit at one hundred, fifty, or twenty-five words) is not helpful, because the character of the subject, the natural habits of the writer, and the power of comprehension of the readers are all different in different cases. So, too, the old-fashioned test which would limit a sentence to the number of words which can be uttered without full pause for breath is useless, for the pauses made in speaking and the division between sentences do not necessarily coincide, and because most subjects which are written are not to be read aloud. There is, however, a test which takes

into account the actual circumstances of the specific cases which is helpful, although it is not so definite and easy to apply as the number or the breath test. Each sentence should contain an idea which is complete as a part of the particular subject matter presented and yet should not be so long that the reader cannot, when he has finished reading it, recall it as a whole by a single act of his attention. The distinction between a paragraph and a sentence should be just this: the paragraph should present a single idea, but one of such complexity that it can be recalled only as a series of facts; but the sentence should be such that it can be readily recalled as a whole grasped by a single act of attention. While the reader is going over the sentence for the first time, he is conscious of getting one idea and then another; but if when he has finished, because of the nature of the subject matter, because of the lack of skill on the part of the writer, or because of his own lack of power of comprehension, he does not grasp the sentence as a whole, but has to think it out again, he has proved the sentence to be,[1] under the circumstances, too long. At the present time careful writers generally are particular not to overburden the grasp of the reader with long sentences. On the contrary, they tend strongly to divide up their thought into sentences so short that they break up the unity of ideas. In the following, for example, the two sentences would be spoken by most without division, and the idea which the writer is conveying is not complete till the end of the second sentence is reached; yet though there are in all but forty words, they are printed as two sentences. "To read this play by the author of 'Cyrano' and 'L'Aiglon' in the original is one thing. To see it presented in an uninspired and mutilated translation, by actors anything but Gallic in spirit and temperament, is

[1] As in the case of this very sentence.

quite another." The safest course for the writer, however, is to attempt to give his readers in each sentence an idea which marks a complete step forward in the development of his subject, yet which is not so complicated but what they can recall it in its entirety as a single step.

"Literary" Qualities Desirable in Technical Writing

313. In addition to the qualities essential to technical writing it is possible to add other qualities which are found in well-written literature of nontechnical sorts. Picturesque language, concrete illustrations, contrasts, paradoxes, figures of speech, references to common experiences or to current or classic literature, "life" of any sort, all may be introduced and may be defended on the ground that even technical subjects do not need to be presented in a dull, dry-as-dust fashion. Yet most technical writers avoid such "literary" qualities, and feel that it is the whole of their duty if they present their ideas accurately, completely, and economically. And certainly it is not desirable to present technical ideas in any way which will attract attention to the form. If there is a play of words, a literary allusion or an illustration used which attracts the reader's attention to the form in which the ideas are clothed, it is by that very fact distracting his attention from the real subject matter. If anything can be added which will keep the reader attentive and interested in the subject itself, whatever the addition may be, it is a gain. And even the barest statement of fact should be given, as far as possible, a form which is as smooth, as euphonious, as finished, as if it were the work of a literary artist. If the writer is attempting to attract general readers to his

subject, he needs to use all his skill to make his presentation interesting. If he is addressing only those whose business it is to get the ideas he has to communicate, he should not feel obliged to "sugar coat" what he is presenting; on the other hand, he should not make his expression difficult, dry, or unpleasant reading.

CHAPTER XII

METHODS OF WRITING

The writing of short reports, § **316**.
The writing of short treatises, §§ **317–327**.
The writing of longer treatises, § **328**.
The methods of more experienced writers, § **329**.

314. Up to this last chapter we have been considering mainly the logical structure and the form of the final writing; that is to say, we have been studying the results which the engineer should strive to bring about in his writing. It remains for us to consider briefly how those results may be obtained, in what way one may produce the most effective technical writing most economically. No one method is equally satisfactory for all subjects or for all writers. Each writer should determine his method for himself and vary it according to the special character of the different subjects on which he writes. The suggestions which follow are worth serious consideration, however, and should be of assistance to the engineer in determining how he can write most rapidly and most effectively.

315. According to the problems of composition which arise, we may divide technical writings into three classes: short reports, in which the main thing is to give adequate record of facts; short treatises, in which in addition to the record of facts there is the need of studying out the best plan of treatment; and long treatises and books, in which the problems of logical structure are the most serious. We shall consider in this chapter these three classes of writings.

The Writing of Short Reports

316. The short report is usually a simple statement of facts which does not put much demand on the ingenuity of the writer, for the reason that the form of presentation is largely determined for him. He must gather his data, completely and accurately, and he must criticize his facts in order that he may give just the information his special readers will want and no more. All this he may be able to do satisfactorily in his head; if not, he will probably find that brief jottings on a scrap of paper will give him as much assistance as he needs in planning. In making out even a short report it is not wise to begin the actual writing till the facts have been carefully tested in the light of the needs of the readers and the plan of treatment has been thoroughly considered. As soon as the writer is sure that he has satisfactorily determined his facts, he needs to consider the form in which he can present them best; everything which the habits of the profession permit of his expressing by drawings, photographs, tables, or diagrams should be so expressed, and the rest of the facts, which must be given in words, should be so arranged as to weave the whole into a continuous report. If the logical structure offers any special difficulties in determining the order, the division or the grouping of the facts, the Introduction or the Conclusion, they will be the same as arise in writing "short treatises." The making of the final draft is simply a problem of presenting the verbal explanations in concise and accurate technical language.

The Writing of Short Treatises

317. The chief difference between the short report and the short treatise, as the terms are used here, is that while the form of the report is largely determined for the

writer by the facts which he is reporting and by the habits of his profession, the treatise may be shaped in many different ways, so that the serious problem of composition in this case is that of deciding which will be the most effective form of presentation. Some do not realize the importance of studying the way of treating a subject, for the reason that any treatment that happens to shape itself in their mind at the moment seems best; but no subject is properly expressed till it has been given the form most effective for the reader.

318. **Letting the subject grow.** — It may be that the writer can beat the subject into shape at a single sitting; but often the position of the reader toward the subject is so different from that of the writer, or the subject itself is so complicated or is capable of being treated in so many ways, that little can be done in such a direct fashion. A difficult piece of composition often will "grow" much more easily and much more effectively than it can be forced. If the writer has it in mind and gives it a moment's thought now and then, under different circumstances and, if possible, at intervals remote enough so that the idea of one time does not dominate his thought at the later time; and if he makes brief notes each time he considers the subject, he will often find that it is gradually shaping itself without hard labor on his part, and that he has a much broader grasp of the matter itself and surer insight into the needs of his readers than as if he were to attempt to build the treatment up all at once. The more difficult and the more important the creative work of the writer is, the more certain he is to reach satisfactory results if he allows the subject to shape itself slowly.

319. **Getting the subject matter on paper.** — When the writer feels that he has his subject matter well in mind, he is ready to give it definite shape; but if his mind is

full of it, careful planning may seem altogether too slow a process. In such cases it is usually better to write out the whole, not to give it proper expression, but to get it on paper. In this way all of the freshness and power of the original interest, which might otherwise be lost in the cold process of methodical construction, may be saved.

320. **Determining the outline.** — For those whose mind has a specially logical bent, it may be best to determine the exact structure at the start; for others it may be better to leave that till the subject has had time to grow, or even till it has been fully written out in a rough draft. At whatever time the process of determining the logical structure is reached, however, two principles should be carefully observed. First, it is better to decide on the main divisions, then the subdivisions, than to attempt to plan the whole treatment step by step from beginning to end. Second, the main divisions should not necessarily be determined in the order in which they will appear in the final writing, but rather in the order of their importance in shaping the exact nature of the subject in the mind of the writer.

321. In those cases especially where the writer finds difficulty in getting his subject into satisfactory form, it is well for him to consider first of all the *Conclusion* (60–62). If the subject will be satisfactorily complete when the last detail of the Body is explained, then it is evident that the Conclusion needs no special attention at the start; but if a real Conclusion is needed, that is the objective point of the whole writing, the definite conception which the writer wishes to build up in the reader's mind. If the writer gets that clearly defined, he not only is sure where he is to end, but is enabled to make every point he introduces tend in that direction. It often happens that after a writer has floundered about

for some time without being able to get his subject into shape, if he defines exactly his Conclusion, he finds that the earlier parts of the paper immediately fall into their natural places.

322. After the Conclusion is shaped in its main features, or after the fact that no formal Conclusion is necessary is established, it is usually best to decide next upon the main divisions of the *Body.* By that means the general trend of the development through which the Conclusion is reached is shaped, and, what is more important, the scope of the subject is determined. To do this the writer must consider (34) just how much his own knowledge and experience enables him to write, how much the circumstances under which he is writing will permit him to include, and how much of what he might write is of real value to his readers; and finally out of the materials which these processes of selection bring together he must shape a subject which has unity and completeness. This part of the planning needs to be done with great care, otherwise the writer is in serious danger of explaining matters which would better be omitted and of omitting parts essential for the readers' understanding, or of presenting a treatment which is rambling or seems incomplete.

323. When the subject matter is clearly in mind and carefully outlined in its main divisions, and generally not before then, it is well to determine exactly what needs to be explained in the *Introduction* (56-69) and to select the *Title* (63, 172, 173). If the writer shapes the Introduction first, he may include much which is not needed for the particular treatment of the subject which is actually to be given, and he may fail to take up some preliminary matters which need to be explained. It is safer to attempt to bridge over from the knowledge of the readers to the subject matter to be presented and

to choose the Title which is to attract the attention of the readers to the particular subject, after the exact nature of that subject matter has been determined by outlining the Body and the Conclusion.

324. **Combining the details into a logical structure.** — How far the subject should be developed in the *outline or synoptic form* depends upon the way in which the individual writer can work most effectively. One writer will find that a brief general outline is all he needs to note down before he begins the final writing; another will gain by developing the outline into a fairly complete synopsis which shows the order, division, and grouping of all the important facts; still another will find it more satisfactory to write an outline of the subject first, then a rough draft, then a topical synopsis, and so work back and forth till the subject finally becomes satisfactorily shaped. If the subject is complicated enough to call for such elaborate treatment, it is often an advantage to put the topical heading of each division on a separate piece of paper and develop the topic thereon, in order that any topic may be thoroughly revised or re-written without interfering with any of the others.

325. In all cases it is important *to test the whole subject* thoroughly to see that the details are logically combined. The essential things to note are three: First, the order (48–54) from beginning to end should be logical, that is, such that the readers addressed will follow it easily and gain at each step the largest amount of understanding and the smallest amount of bewilderment. Second, divisions which the synopsis marks as of the same grade should in all cases be in fact strictly coördinate (42). Third, the sum of the subdivisions of any larger division should be equal to the whole of that division, no more and no less (43–47). In the synoptic form these points may be easily tested; therefore, wherever there is any

question as to the logical structure of a part of a subject, the best and the quickest way to settle the question is to write out at least that part fully in the synoptic form.

326. **Writing the final form.** — In writing the final form of a short treatise, it is necessary, first, to determine how much is to be included in each paragraph. This may easily be indicated by drawing lines across the outline or synopsis to mark the division places between the paragraphs. Some of these paragraphs will need to be bound together verbally into groups (278), and this may be indicated on the synopsis and the words which are to be used to indicate the grouping may, if necessary, be noted. If this does not make the structure of the paper as clear to the reader as it should be, the required paragraphs of relationship, headings, and differences in type may be indicated (280–285). As the actual writing progresses, the inner structure of the paragraphs (256–266) should be carefully developed, and the sentences should be so constructed that they are strictly grammatical (306), of satisfactory length (310–312), and properly massed to bring out the right emphasis (303–305). From the first, words should be chosen as far as possible which are accurate, technical (287–288), clear to the reader (289–292), and economical (295–298); but before the actual final draft is made, the whole subject should be read over with the attention centered upon the words. In doing this, it is well to read aloud, for by that means ill-sounding combinations and awkward sentences are much more readily detected.

327. **Preparing the Ms. for the printer.** — It is well for the engineer to form the habit of putting his writing into such shape that it may be conveniently used by a printer, even when he has no thought of having his treatise printed. For this purpose, a few simple rules should be observed: —

White paper of ordinary thickness and of uniform size, about eight inches wide and eleven inches long, should be used, and should be kept flat even in mailing.

The pages should be numbered consecutively throughout. Inserted pages should be lettered (for example, pages inserted between page 10 and page 11 should be numbered 10a, 10b, etc.), and any pages removed after the following pages have been numbered should be accounted for on the preceding page.

The writing should be on one side only.

There should be a margin of from one inch and a half to two inches on the left-hand side, and a space of an inch at the top of each sheet.

Time and expense are usually saved by having the manuscript typewritten.

Reference to a footnote should be indicated at the proper place by an asterisk (*) or more commonly now in printed books by small superior figures. If two or more footnotes are referred to on a single page, they should be numbered consecutively. Short notes should be written immediately after the line where the reference occurs and cut off by lines drawn across the page, thus: —

---

* Note.

Notes of more than a few lines should be written on separate sheets, placed next to the sheet containing the reference and numbered consecutively with the text.

Illustrations of any sort should each be on a separate sheet, carefully numbered, and clearly referred to at the place in the text where each occurs.

If the writer is sure of the differences in type which he wants observed, he should mark all places where there is to be deviation from the type chosen for the main part of the text, by the use of the usual signs, *after he has completed his manuscript.*

	italic.		capitals.
	small capitals.		italic capitals.
	bold-faced lower case		bold-faced capitals.

The "point" or size of type generally should be settled either by or in conference with the publisher, but if finer print is to be used in part, the special places should be marked by the author.

THE WRITING OF LONGER TREATISES

328. The problem of writing longer treatises is much the same as that of writing short articles except that it is more complicated. More time is needed for the "growth" of the subject. It is seldom that anyone is fitted to write anything the length of a book till he has had the subject in mind for some years and has given much thought to the planning of it. In the same way there is more occasion to work back and forth from rough draft to synopsis. For purposes of writing, a treatise long enough to be divided into chapters may be treated during a considerable part of the composition as a series of short treatises, the chapters. The general plan of the book as a group of chapters needs to be made out at the start, and may have to be revised several times during the process of developing the subject; but just as soon as the exact nature of a chapter as a division of the book is determined, that chapter may be taken by itself and written as if it were a separate subject, except that its Introduction, instead of resting on the assumed knowledge and interests of the readers, may rest on the explanations of the preceding chapters, and that the Conclusion, instead of giving the subject final shape for the reader, should shape it for the chapters to follow.

Methods of More Experienced Writers

329. Much of the writing of engineers and technical experts has to be done within narrow time limits which would seem to give no opportunity for such preliminary study of the problems of expression as has been suggested. But even when time is very short, better results will be obtained if a considerable portion of that time is spent in careful planning before the final draft is started, than if the actual writing is begun at once. Training or native skill does not enable a writer to dispense with planning; it rather makes it possible for him to shape the subject rapidly and almost unconsciously in his head. Generally, however, those who write without consciously studying the problem of expression turn out product which does not give the readers the information they wish or which puts upon them burdens they should not be asked to bear. In dealing with any but the simplest subjects, the success of a writer depends, as one who was himself an effective writer and a most successful teacher once said, upon the willingness of the writer to fill a waste basket if necessary before producing a single finished page. And the ability to turn off rapidly daily reports, business letters, or editorials usually comes from the fact that the writer has on other occasions and perhaps in dealing with more complicated subjects already filled his waste basket.

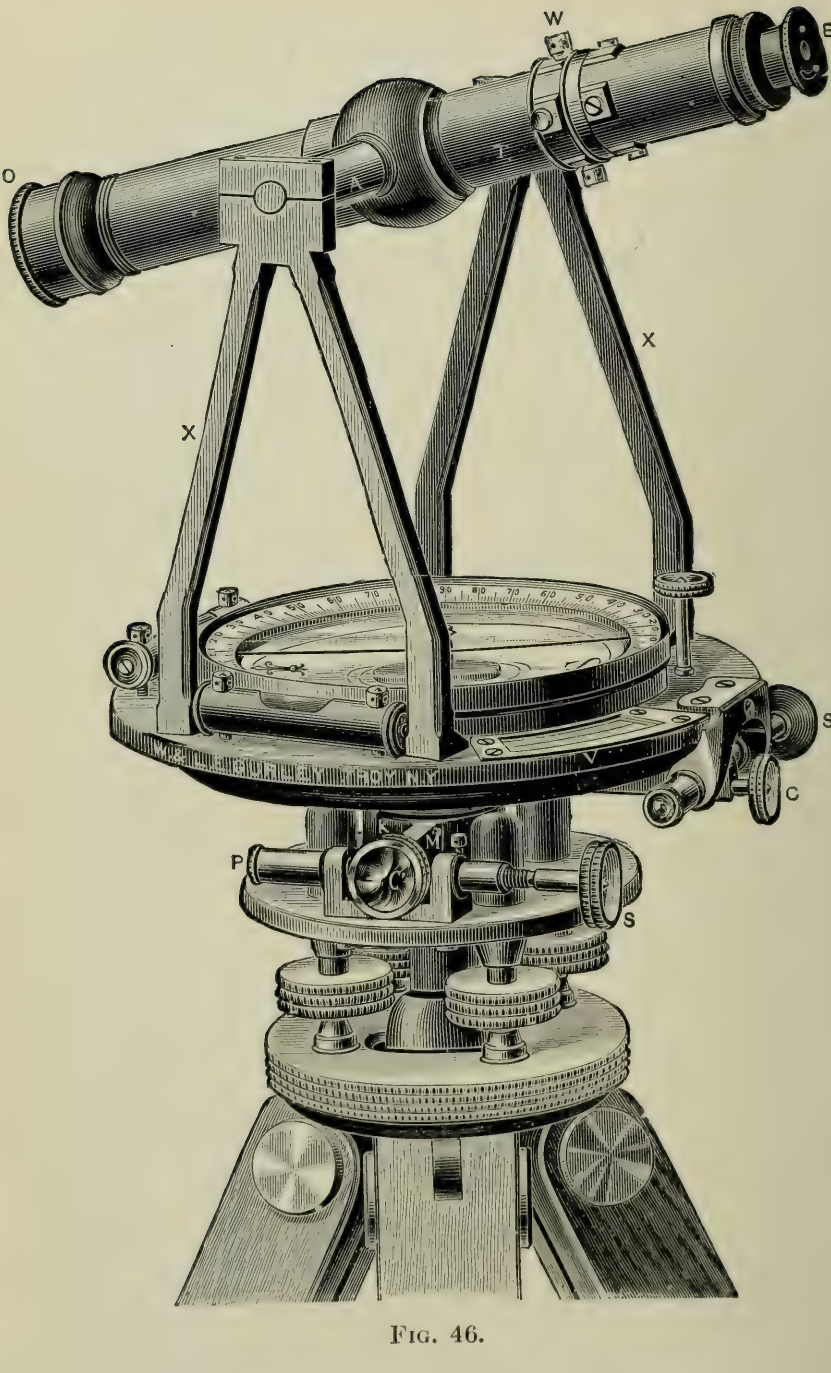


FIG. 46.

APPENDIX

ILLUSTRATIVE EXAMPLES OF TECHNICAL WRITING[1]

I

The Transit

(A portion of § 81 from "A Text-book of Plane Surveying," by William G. Raymond, C.E. Printed with the permission of the American Book Company.)

1. **Description.** The instrument most used by surveyors and engineers for measuring horizontal angles, and, with certain attachments, for measuring vertical angles and distance, and for leveling, is called a transit.

2. The transit consists of a telescope attached to a pointer which may be moved around a graduated circle. There are suitable attachments for controlling the motion of the telescope and the pointer, and for enabling the graduated circle to be made horizontal. The pointer may be clamped to the graduated circle, and they may be revolved together. If this is done, and the telescope is pointed to a given object, and the graduated circle is clamped so that it will not revolve, and if the pointer is then unclamped from the circle, the pointer and telescope may be turned together till the telescope points to a second object. The number of degrees of the circle over which the pointer has passed will be the angle subtended, at the point where the transit is placed, by the two objects seen through the telescope.

3. The pointer is the zero mark of a vernier. There are usually two double verniers placed 180° apart.

4. In the transit shown in Fig. 46, T is the telescope, which may, by means of the horizontal axis A, be revolved in a vertical plane.

5. The horizontal axis rests in bearings at the top of the

[1] See § 184.

standards X, which are rigidly attached to the circular plate that carries the vernier V.

6. On this plate are set two level tubes which, when adjusted to be parallel to the plate, will show whether the plate is level. This plate is made by the maker perpendicular to the axis on which it revolves, and hence, when the plate is level, the axis of revolution is vertical. This axis is conical, and fits inside a conical socket which is the inside of the conical axis of the plate that carries the graduated circle. This latter conical axis revolves in a socket that connects the top and bottom plates of the leveling head. The upper plate is leveled by the leveling screws L. The lower plate of this leveling head screws on to

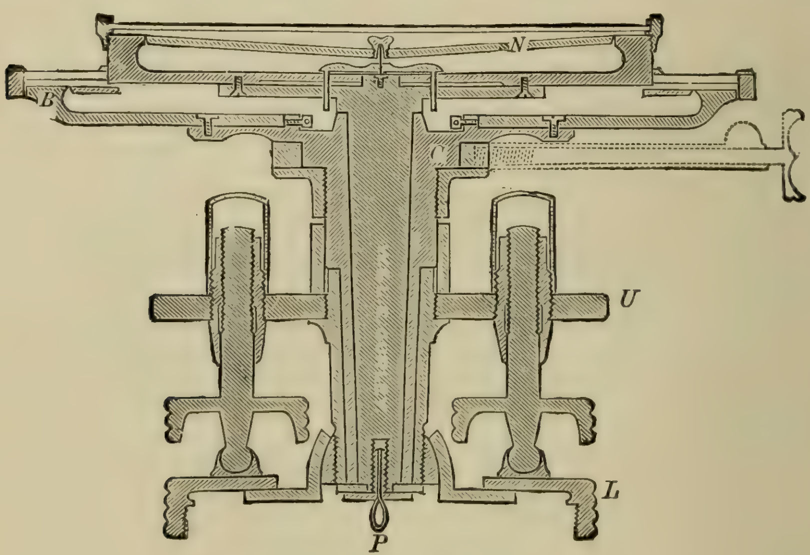


FIG. 47.

the tripod. The clamp C fastens together the vernier plate (sometimes called the *alidade*) and the plate carrying the graduated circle. The latter is called the *limb*. When the two plates are clamped together, the vernier plate may still be moved a small amount, relatively to the limb, by means of the tangent screw S. This is for the purpose of setting the vernier at a given reading, or pointing the telescope at a point, more precisely than would be ordinarily possible by simply turning the alidade by the hand. The collar K surrounds the spindle of the limb, and by the clamp screw C' may be fastened to that spindle. The lug M, which is attached to the collar, being held by the

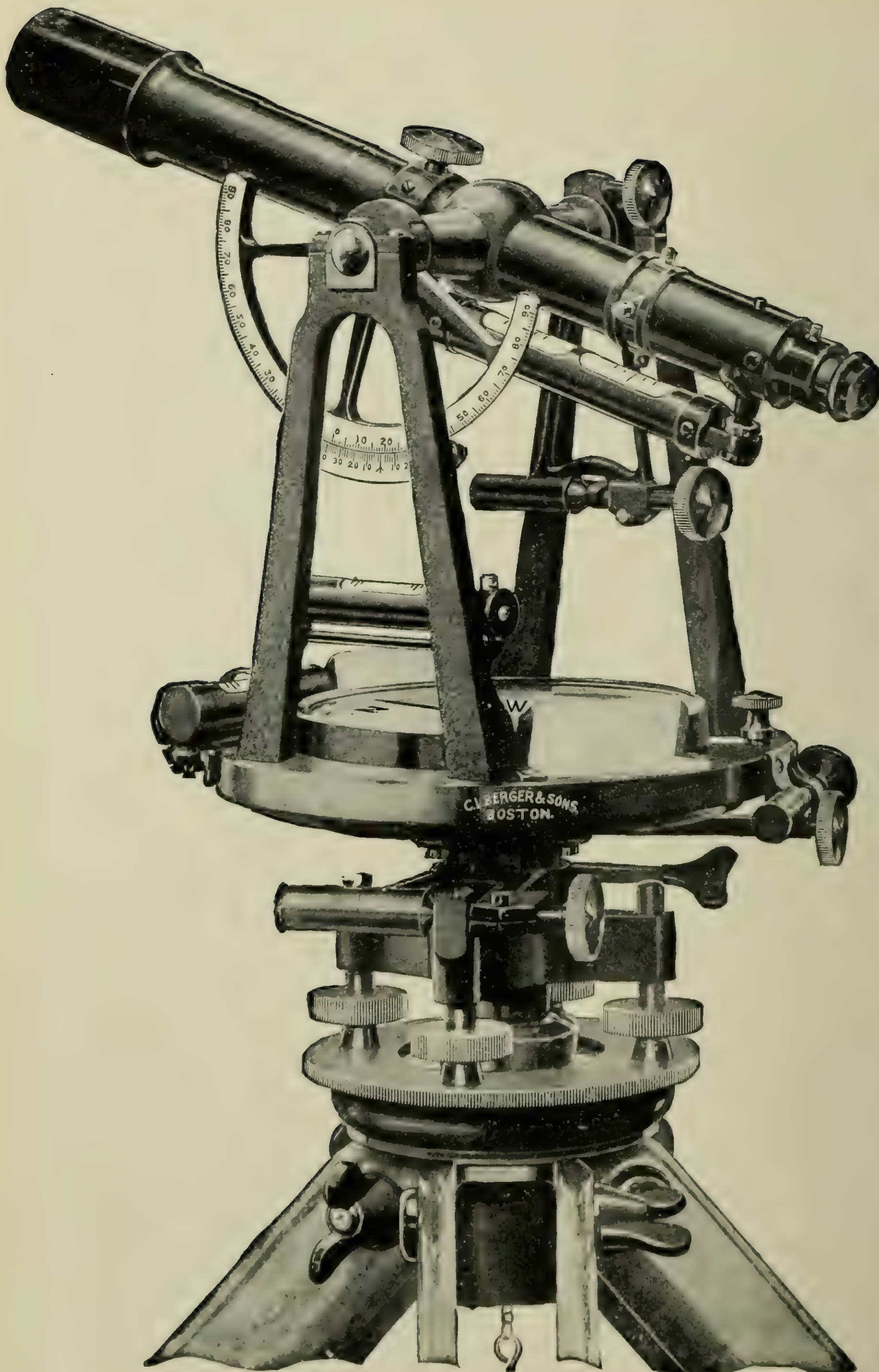


Fig. 17.

spring in the barrel P and the opposing screw S', in turn fastened to the upper leveling plate, prevents the revolution of the limb, when the collar is clamped to its axis. The limb may, however, be moved a small amount by the tangent screw S' working against the pressure of the spring in the barrel P.

(Referred to in §§ 22–25, 70–74, 155, 156, 160, 161, 174, 177, 180, 181, 183, 290, 309.)

II

The Transit

(Section 86 from "The Theory and Practice of Surveying," by J. B. Johnson, C.E. Sixteenth edition. John Wiley and Sons, 1907. Printed with the permission of T. E. Turneau.)

1. **The Engineer's Transit** is the most useful and universal of all surveying instruments. Besides measuring horizontal and vertical angles, it will read distances by means of stadia wires, determine bearings by means of the magnetic needle, do the work of a solar compass by means of a special attachment, and do leveling by means of a bubble attached to the telescope. It is therefore competent to perform all the kinds of service rendered by any of the instruments heretofore described, and is sometimes called the "universal instrument." A cut of this instrument is shown in Fig. 17. Figure 18 is a sectional view through the axis of a transit of different manufacture.

2. The telescope, needle-circle, and vernier plates are rigidly attached to the inner spindle which turns in the socket C, Fig. 18. This portion of the instrument is called the *alidade*, as it is the part to which the line of sight is attached. The socket C carries the horizontal limb, shown at B, and may itself revolve in the outer socket attached to the leveling-head. Either or both of these connections may be made rigid by means of proper clamping devices. If the horizontal limb B be clamped rigidly to the leveling-head, and the alidade spindle be allowed to revolve, then horizontal angles may be read by noting vernier readings on the fixed horizontal limb for the different pointings of telescope. If the horizontal limb itself be set and clamped so that one of the verniers reads zero when the telescope is on the meridian, then for any other pointing of the telescope the reading of this same vernier gives the true azimuth of the line. It is necessary, therefore, to have two independent movements of

telescope and horizontal limb on the same vertical axis. The magnetic needle is shown at N. The plumb-line is attached at P; this should always be in the vertical line passing through the center of the graduated horizontal circle. This will be the case when it is attached directly to the axis itself, for this must always be made vertical.

3. The limb is graduated from zero to 360°, and sometimes with a second set of figures to 90° or 180°. There are two verniers reading on the horizontal limb 180° apart. Both the instruments shown in Figs. 17 and 18 have shifting centers, enabling

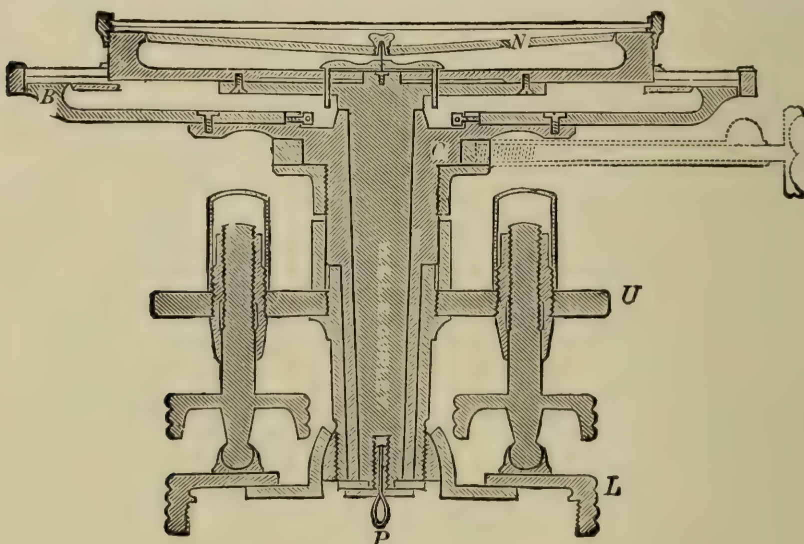


Fig. 18.

the final adjustment of the instrument over a point to be made by moving it on the tripod head. The telescope is shorter than those used in leveling instruments, in order that it may be revolved on its horizontal axis without having the standards too high. It is called a transit instrument on account of this movement, which is similar to that of an astronomical transit used for observing the passage (transit) of stars across any portion of the celestial meridian. When the telescope is too long to be revolved in this way, the instrument is called a *theodolite.* This is the only essential difference between them. The "plain transit" has neither a vertical circle nor a bubble attached to the telescope.

(Referred to in §§ 75, 76, 161, 170, 174, 177, 183.)

III

(An advertisement from an engineering magazine.)

CONCRETE SEWERS

in which the Portland Cement used throughout has been

WATERPROOFED

with our Compound are proven, by the highest authorities, beyond the possibility of furnishing examples of disintegration to be employed by competitive industries as a warning against the use of this ideal method of construction.

(Referred to in §148, note.)

IV

(From a "Descriptive Illustrated Catalogue," entitled, "Machine Tools.")

Turret-head Power Bolt Cutters

1. A revolving turret carries the dies, either one of which may be presented instantly to the bolt to be cut and carried forward by a hand wheel, pinion, and rack. The turret is secured in position by a spring lock-bolt. The head spindle is hollow to receive bolts of any length, and by removing the die opposite the one that is at work, allowing the bolts to project through the turret, the thread may be cut to any distance required. The spindle is furnished with a chuck for holding the bolt or the tap, and is driven by a cone pulley. The chips and oil are caught in the bed, the oil draining free from chips through a strainer into a receiver, from which it can be drawn and used again. The facility with which bolts of different sizes can be threaded (seven or nine bolts of as many sizes being threaded almost as quickly as the same number of one size) renders this style of machine very serviceable and convenient in car shops, and wherever the number of bolts to be cut at a time is small, changes of size frequent, or men carry blanks to a bolt cutter and wait to be served.

2. Each machine is furnished with nut-vise, wrenches, friction

clutch countershaft, and the following sizes of taps and dies, U.S. standard form: —

With No. 3 machine: $\frac{3}{8}$-in., 16; $\frac{7}{16}$-in., 14; $\frac{1}{2}$-in., 13; $\frac{5}{8}$-in., 11; $\frac{3}{4}$-in., 10; $\frac{7}{8}$-in., 9; 1-in., 8; seven sizes.

With No. 4 machine: $\frac{1}{2}$-in., 13; $\frac{5}{8}$-in., 11; $\frac{3}{4}$-in., 10; $\frac{7}{8}$-in., 9; 1-in., 8; $1\frac{1}{8}$-in., 7; $1\frac{1}{4}$-in., 7; $1\frac{3}{8}$-in., 6; $1\frac{1}{2}$-in., 6; nine sizes.

	No. 3	No. 4
Number of grades on cone	3	4
Diameter of largest grade	9 in.	$13\frac{1}{2}$ in.
Width of belt	$2\frac{1}{4}$ in.	3 in.
Floor space	$4\frac{2}{3} \times 2$ ft.	6 ft. × 26 in.
Dimensions of countershaft pulleys	$10 \times 3\frac{1}{4}$ in.	$14 \times 4\frac{1}{2}$ in.
Revolutions of countershaft per minute	145	110
Weight with countershaft	1,280 lbs.	2,575 lbs.
Weight boxed for export	1,800 lbs.	3,300 lbs.
Cubic feet of boxes	74	117

(Referred to in §§ 159, 160, 174, 223, 224.)

V

Wet Machines

(By Edwin Morey, Manager Sales Department, Improved Paper Machinery Co., Nashua, N. H. Printed with the permission of Mr. Morey.)

1. The manufacture of wood pulp, one of the younger industries of the United States, has grown rapidly since its beginning some twenty years ago. The government reports for 1907 show that 258 pulp mills of the United States turned out about three and one-half million tons of wood pulp. They also show that this pulp was made from 3,962,660 cords of wood, valued at $32,507,713, in mills representing an investment of $167,507,713.

2. There are two general processes for the manufacture of this pulp. The wood (in either case) is first cut up into two-foot logs, and the bark is removed. In one process these short logs are pressed against revolving stones and the wood ground to pulp (Fig. 2). In the other process the logs are cut up into chips, which are reduced to pulp by cooking with acid in large boilers known as digesters (Fig. 3).

3. In each case the resulting pulp is mixed with a large amount of water and run over screens consisting of brass plates with

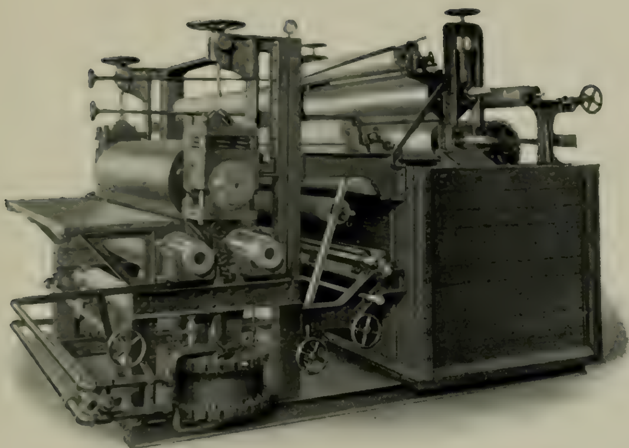


Fig. 1.

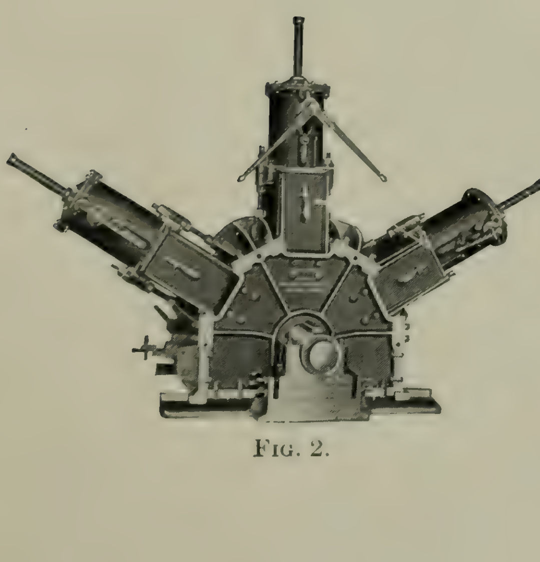


Fig. 2.

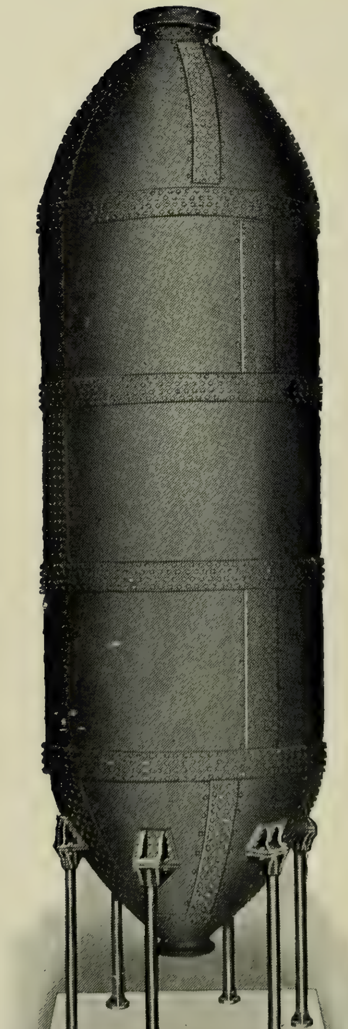


Fig. 3.

slits in them (Fig. 4). The fine fiber passes through, leaving the knots and uncooked parts above.

4. The next step in the process is to remove the large excess of water which has been added. There are several methods of doing this. A common one is to run the mixture into large tanks with porous bottoms and let the water drain off. A better method is to revolve a cylinder, with a fine wire face, in a tank of the mixture; the water passes through the wire and escapes through the open end of the cylinder; but the pulp adheres to the face of the cylinder in the form of a thick skin. A felt-covered roll revolving on top of the cylinder picks up this pulp,

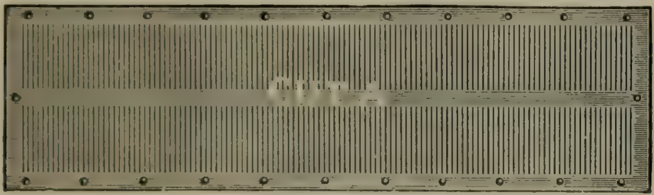


FIG. 4.

and from there it is scraped off, in the form of a thin paste (Figs. 6 and 7). This method is the one generally employed where the pulp is to be used in the mill. If it is to be shipped, the pulp must be made up into sheets, and it is this part of the process which is performed by the Wet Machine (Figs. 1, 5, 9, to 15).

5. The mixture of pulp and water is pumped into a large wooden tank (*a*, Fig. 5), in which slowly rotates a hollow cylindrical drum (*b*) covered with fine wire cloth (Fig. 8). The water passes through the wire and escapes through the ends of the cylinder, but the pulp adheres to the surface in the form of a thin skin. As the cylinder revolves, the skin of pulp is carried up above the surface of the mixture in the tank, where it comes into contact with an endless traveling felt, or blanket (*c*), to which it adheres. The pulp on the cylinder is constantly transferred to the felt, on which it is carried over a suction box, where a part of the water is drawn out by suction. Then it passes between rollers (*e*, *f*, *f*) which squeeze out more water, which is caught in a trough and piped away. At the same time the pulp adheres to the upper roller, leaving clean felt to travel back. The pulp is wound around the upper roll, forming one thick sheet. When it is of sufficient thickness, the operator

runs a sharp stick across the face of the roll, cutting the pulp into one sheet. These sheets as they are taken from the roll are folded up into a convenient size, and are ready for shipment. The pulp at this stage contains about 60 per cent of water.

6. There are two distinct types of Wet Machines, those having two press rolls (Fig. 9, 10, 11), and those having three press rolls (Figs. 1, 5, 12). These types are manufactured with one or

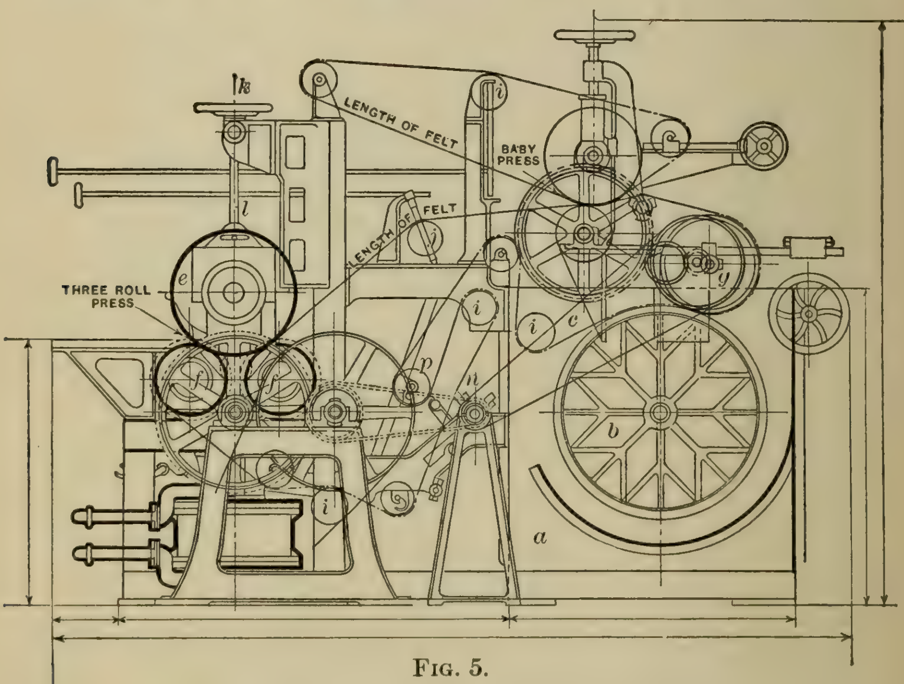


FIG. 5.

two tanks, and are called single or double cylinder wet machines. Figures 12, 13, are types of two roll double-cylinder machines.

7. The mixture of pulp and water is piped from the screens directly to the tanks of the wet machines. These tanks are generally made of wood (Figs. 1, 5, 11), but sometimes the ends are of cast iron (Fig. 12). The whole tank may be made of iron castings, as shown in the two-roll design (Figs. 9, 10). The cast iron ends are better adapted for holding the bearings for the cylinder mold, and waste water piping can be more easily connected, for when wooden ends are used, the bolts are liable to work loose in the wood. The tanks must be water-tight. In making the iron tanks the castings are bolted together, and the space between the joints is filled with melted lead.

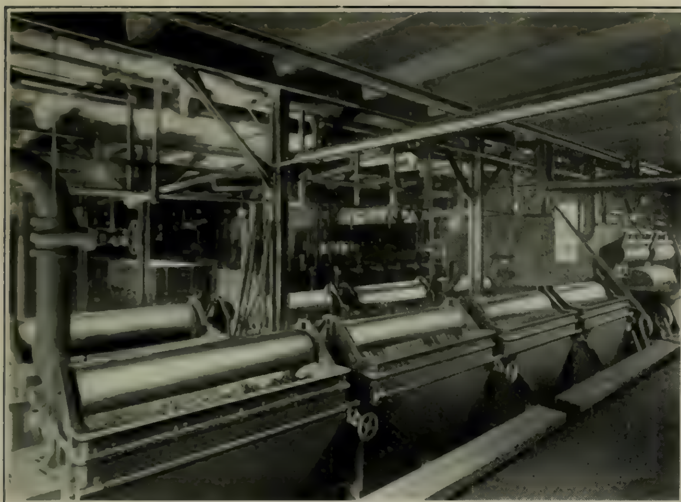


Fig. 6.

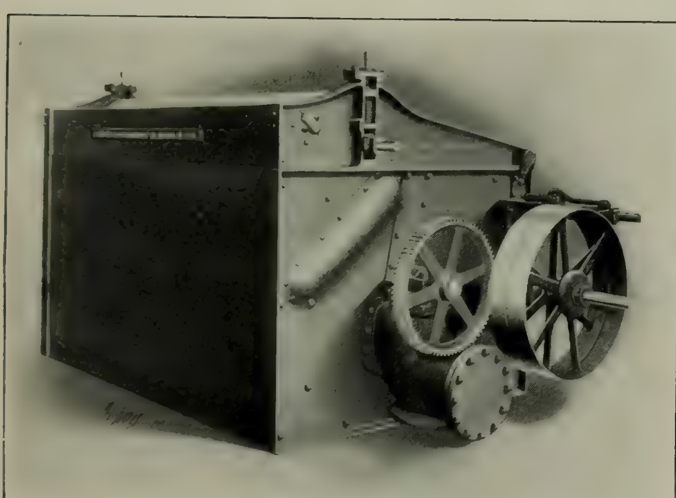


Fig. 7.

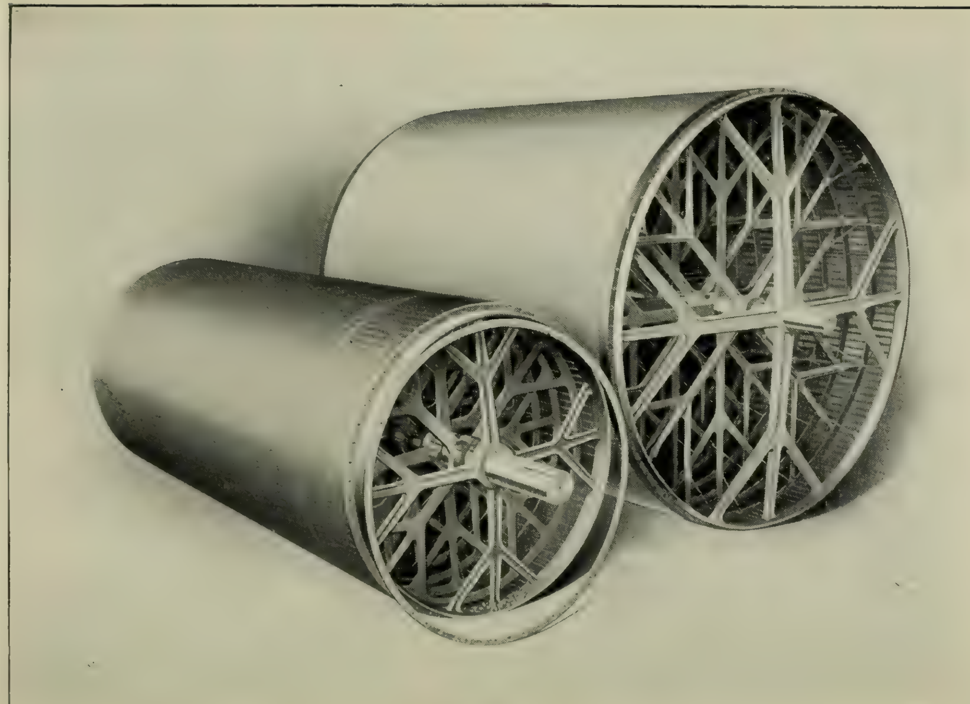


FIG. 8.

8. The cylinder mold (Fig. 8) is made up of brass spiders evenly spaced upon a steel shaft. Grooves are milled on the circumference of these spiders to hold brass rods. The end spiders are a little larger, and holes are drilled in them to hold the ends of the rods. Grooves are then cut in the rods, and copper wire is wound around. This winding is done in the lathe, and the wires are about an eighth of an inch apart. Fine wire cloth is stretched on the outside of the winding wire. The edges of this cloth are turned over the end spiders, and a hoop is screwed on to hold the wire cloth in place. A belt of cotton duck is sewed around the ends of the cylinder mold to narrow up the working face. The outside spiders have lips which project about an inch. A similar projection of wood is fastened to the inside of the tank. These projections are of the same diameter, with only a slight clearance between them. A rubber belt is passed around and laced up tight to prevent the stock from leaking around the edges of the cylinder mold.

9. The couch roll (*g*, Fig. 5) is made of wooden staves bolted to two iron wheels. Its bearings are hung on two levers, which are weighted to press the couch against the cylinder mold. This causes the pulp to stick to the felt instead of following the cylinder back into the tank.

10. The felt (*c*) is an endless blanket of pure wool. It acts as a carrier for the pulp in this wet state, and also as an absorbent. The felt is made all in one piece to avoid seams, and the machine is so designed that this felt can be slipped on over the ends of the rolls.

11. This felt is carried by felt rolls (*i*, *i*, *j*). These rolls are made of white-wood logs about six inches in diameter. The shafts are made of hexagon steel, driven into the ends and turned down to the bearings. The bearings of the guide roll (*j*) are hung on pivoted levers, and are so arranged that by turning a small hand wheel this roll may be swung back and forth in order to guide the felt into the center. The felt may stretch unevenly and become longer on one side than on the other. This would cause it to run to one side, where it would catch in the bearings and tear. When the machine is running, an operator must watch this felt and adjust the guide roll so that the felt always runs in the middle.

12. The suction box is hollow; the face in contact with the felt is filled with either holes or slits. The inside of this box

is connected to a suction pump, and as the pulp on the felt passes over the box, water is sucked out.

13. The press rolls (*e*, *f*, and *f*) are generally made of solid rock maple logs. The logs are turned when the wood is still green, because a dry log would check and be useless as a press roll. Heavy cast iron heads are fitted into the ends of the log, and eight wrought-iron rods are run through, bolting them together. In order to get high tension, the rods are heated to expand them, and the nuts are screwed on before they cool. As the rods cool, they contract and pull the heads together with great force. Care has to be taken not to screw the nuts on too far, for the contraction may be sufficient to snap the rods. The larger the diameter of these press rolls, the better, but they are limited by the size of the rock maple logs obtainable. Press rolls are often made of cast iron, but the large sizes are too heavy to handle. These rolls of course last longer than the rock maple logs, but they are very hard on the felts, and the pulp sticks to them so tight that they are not universally used. There is a patent roll made up of sections of wood fitted into a cast-iron core with the end grain out. The wood is put in dry, and allowed to swell. This makes a roll that wears well. The majority of wet machines now on the market are fitted with iron bottom rolls and rock maple top roll.

14. Pressure between the rolls is obtained by heavy car springs, as shown in Figs. 9, 10, and 11. The hand wheel (*k*), which is fast on the screw (*l*) is screwed down compressing the car spring. This spring gives the top roll a chance to rise as the thickness of pulp increases. Another method is to hang heavy weights on the ends of long levers, the bearing being on the short arm. Still another method is the hydraulic press, as shown in Figs. 1, 5, 12, and 15.

15. The pulp on the felt passes between these rolls where about half the water is squeezed out. The pulp is wound around the top press roll until it is the desired thickness, then it is cut off and folded into bundles.

16. The felt passes around the bottom roll on its way back for more pulp, but before it picks up pulp again, it must be washed with a shower of water. The whipper (*n*) snaps the felt back and forth as it is stretched between the two felt rolls and the water and dirt are whipped out of it.

17. The bearings of the felt roll (*p*) are hung on two screws

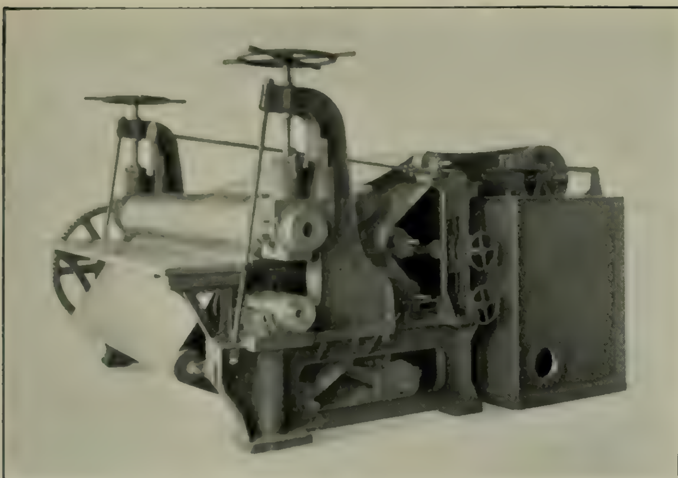


Fig. 9.

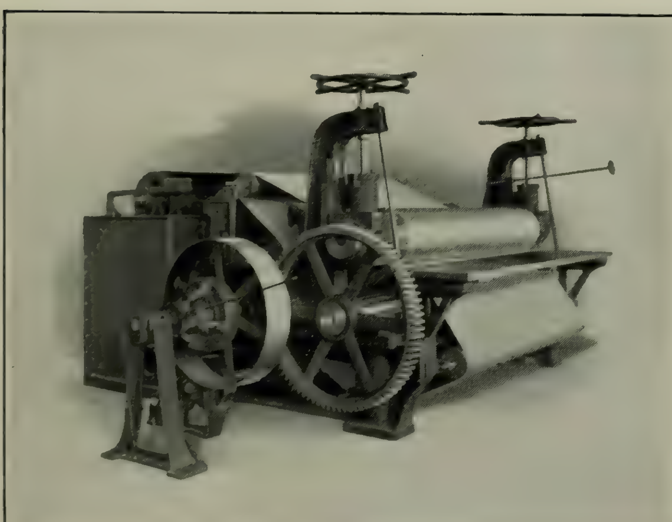


Fig. 10.

FIG. 11.

so that they can be adjusted up and down. This adjustment is to take up the slack in the felt, which must be kept tight.

18. On a double-cylinder machine an auxiliary felt, known as a back felt, must be used to carry the sheet of pulp from the back cylinder and deposit it on top of the forward sheet, so that they can be pressed together (Fig. 13).

19. The wet machine is operated by one man, although he generally has an assistant to help him get the sheet started. Sometimes the sheet will start itself, but more often it will stick to the cylinder, instead of being picked up by the felt. If the sheet does not stick very hard to the cylinder, it can be lifted off with the fingers and started up over the couch. If the suction is too great on the inside of the cylinder, and the pulp sticks hard to the cylinder face, the sheet may be started by flooding the inside of the cylinder until the sheet comes off easily. The flow of the waste water must then be regulated up to the point where more suction would cause the sheet to cling to the cylinder.

20. The pressure on the press rolls must be increased until more pressure would cause the pulp to crush. As the pulp winds around the top press roll, the operator must watch it until it is of such thickness that when it is removed and folded up into a bundle it will weigh very close to one hundred pounds. An expert operator can estimate the desired thickness so close that the bundles vary only six to eight pounds. The pulp is removed by running a sharp pointed stick across the face of the roll under the pulp, cutting it into one sheet of the same width as the roll and of the length of the circumference. This sheet is folded up into a bundle, and put on to scales where a piece of pulp is added or torn off to make the bundle just one hundred pounds.

21. Samples are taken at intervals and tested to determine the percentage of water. The dry weight of the bundles is then calculated, and the pulp sold on the calculated weight.

22. It is a well-known fact, that more water can be squeezed out of anything by running it through a second time. Therefore by using three rolls, which squeeze the sheet twice, instead of two rolls, which squeezes it once, dryer pulp can be made. Four rolls can squeeze the sheet only twice, so by using the three-roll type the same result is obtained at less cost. The felts last longer with three rolls because the pounding due to the press rolls coming together as the thick sheet is being removed is

obviated in the three-roll machine; one of the bottom rolls supports the upper roll as the edge of the thick sheet comes through. The blow, instead of being a quick blow, which cuts the felt, is only a rolling motion which is not hard on the felt.

23. Double cylinders are used when it is desired to increase the capacity at the expense of dryness. The two cylinders pick up twice as much stock, but the same pressure on the press rolls will not squeeze it so dry.

24. The hydraulic press is the best type, because it is more uniform and constant, as the thickness of the sheet increases, than either the car spring or weighted lever types. By placing the hydraulic cylinder below the bottom rolls, in order to pull the top roll down, greater pressure can be obtained without the necessity of heavy frames, which are required when pushing down from above.

25. Generally about half the weight of the pulp as it comes off the machine is due to the water in it. If the pulp is to be shipped, the freight on the excessive amount of water is quite a sum, and it pays to use improved machines in order to get dryer pulp. The economic amount of dryness depends directly upon the cost of transportation.

26. An ordinary wet machine having an 84-inch face will have a capacity of about twenty-five tons, 40 per cent dry, per twenty-four hours. About 15 horse power will be required to run it.

27. These machines are in constant use, being run twenty-four hours a day, and they probably get as hard use as any in a pulp mill. There are several defects in the design that are yet to be overcome. The most serious of these is due to the fact that most builders make their designs too light, and light designs are constantly in need of repair. The bearings on the press rolls are yet to be perfected. These bearings are under about ten tons pressure, and they are subject to severe shocks. The result is that most mills have to have an extra machine ready to start up while these bearings are being replaced. Wooden press rolls are most generally used, although they splinter, and when not in use they crack easily, which makes them useless.

28. Iron rolls would be better than the wooden if the pulp did not stick to them so tight, and if they were not so hard on the felts. When two iron rolls come together as the sheet is taken off, they cut the felt and soon break it apart. Pulling the felt over the suction also destroys its life. These felts are

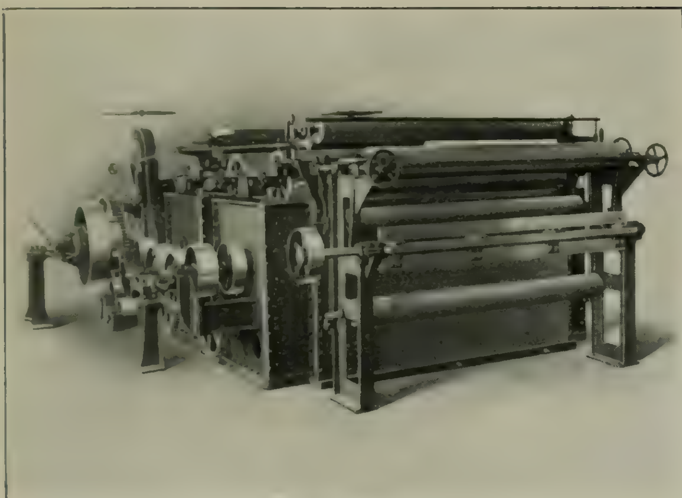


Fig. 12.

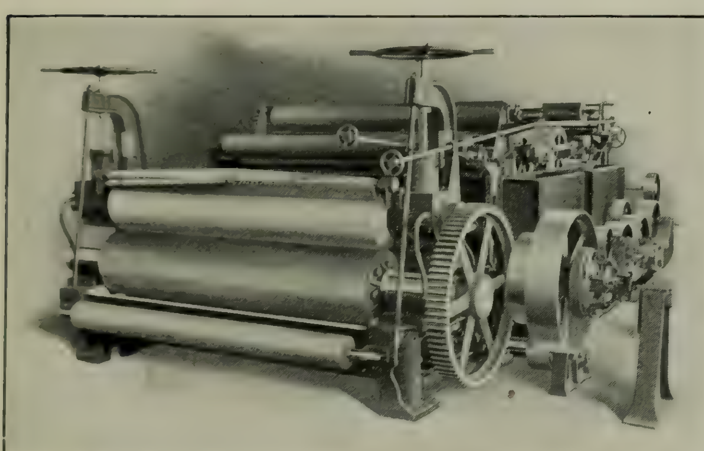


Fig. 13.

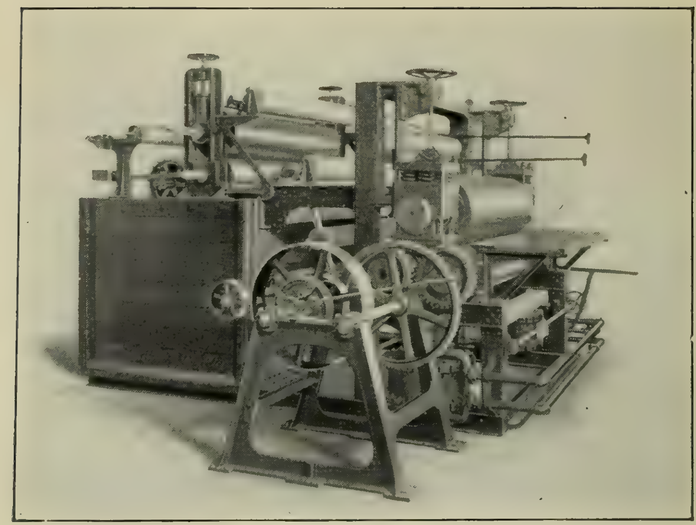


FIG. 14.

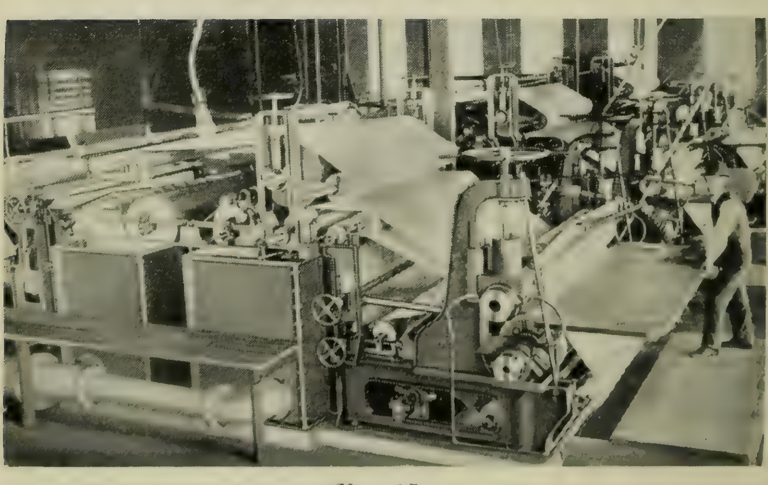


FIG. 15.

very expensive, and even on the best machines last only a few months.

29. At the present time the tendency of manufacturers is to design a wet machine that will have a large capacity yet deliver the pulp as dry as possible. Figure 15 shows one of the latest designs in wet machines. Figure 16 shows a battery of the two-roll type in operation in a mill.

(Referred in §§ 155, 159, 160, 161, 162, 164, 168, 170, 174, 180, 183, 197, 198.)

VI

Potable Water

(By M. N. Baker, Ph.B., C.E. First chapter, entitled "Introduction." Printed with the permission of the publisher, D. van Nostrand Company.)

1. Potable water is water suitable for drinking, whether made so by nature or art. While less than 1 per cent of the water supply of a city is used for drinking and culinary purposes, it is the almost universal practice to attempt to have the other 99 per cent potable water also. This is due partly to the great cost and inconvenience there would result from a dual supply, and partly to the danger that if two supplies were available the one would be taken for drinking purposes which happened to be most convenient at the moment, regardless of its quality. Without pursuing this phase of the subject further, it may be assumed that under present conditions the whole water supply of a city or town must be potable.

2. The minimum quantity of water which may be considered as sufficient for a city supply is a daily average of one hundred gallons per capita. To secure this amount of potable water is becoming more difficult year by year. This is due to a variety of reasons, chief of which are increasing urban populations and a standard of purity which is constantly rising. The increase in population makes the problem doubly hard, because it means a demand for water in advance of the rate of accession to the population, and a diminution in the quantities of pure water available. All these things join in making determinations of the potability of water much more essential and far more in demand than heretofore. In the case of existing supplies it becomes necessary to study them closely to determine whether they are approaching the danger limit, and what, if anything, can be done to avert

the danger, either by diversion of pollution or some method of purification. When it is decided to go afield for new sources of supply, these must be studied with great care. Where purification is attempted, frequent and careful examination of the water must be made to determine whether the best results are being attained at a minimum expense.

3. The foregoing considerations suggest the following outline of the contents of this volume: —

I. What constitutes potable water.
II. How potable water may be secured.
III. How to detect impurities.
IV. Some notable laboratories.

4. To avoid possible misunderstanding, it may be said here that the aim of this little book is not to present a manual on any phase of waterworks design or construction, or on the examination of water, if that were possible in so small a compass. What is desired is to indicate clearly the proper standards for potable water, how these may be realized, and how the results actually attained may be judged.

(Referred to in §§ 161, 163, 164, 179.)

VII

Interpolation

(Used by the Mathematics Department of the Engineering School, Tufts College.)

1. Interpolation is a method of obtaining from a table the function of an argument entered in the table. It rests upon the assumption that in the gaps between the numbers tabulated an increase in the argument is accompanied by a proportionate increase in the function. This assumption is justified when successive tabular intervals (differences between consecutive arguments) are equal, and successive tabular differences (differences between consecutive functions) are equal. Thus from the table of square roots here shown we find the square root of $51\frac{1}{4}$ by adding to the square root of 51 a quarter of the difference between $\sqrt{51}$ and $\sqrt{52}$; that is, we take $7.14 + \frac{1}{4}(7.28 - 7.21)$ or $7.16 = \sqrt{51\frac{1}{4}}$.

(N. arg.)	($\sqrt{N}$ func.)
50	7.07
51	7.14
52	7.21
53	7.28
54	7.35

2. As a further illustration, we may get by interpolation the mantissa of the logarithm of 35174, using the following extract from a table of logarithms: —

N	0	1	2	3	4	5	6	7	8	9
350	54 497	410	432	444	456	469	481	494	506	518
51	531	543	555	568	580	593	605	617	630	642

The given number is between 3517 (0) and 3518 (0). The interval between these arguments is 10, and the tabular differences between the corresponding mantissas, 54,617 and 54,630, is 13. The given number is the sum of the first argument and $\frac{4}{10}$ of the tabular interval, and its mantissa should be the sum of the first mantissa and $\frac{4}{10}$ of the tabular difference ($\frac{4}{10} \times 13 = 5 +$). We thus obtain 54,622. The fifth digit, therefore, shows how many tenths of the tabular difference should be added to the first four digits.

3. The mantissa of a number of six digits may be found from this same table by considering the two extra digits as giving the number of hundredths of the tabular difference to be added as correction. Trigonometric functions are commonly tabulated for angles at intervals of one minute: the function of an angle given to seconds may be found by considering that the seconds give the number of sixtieths of the tabular difference to be added as correction to the tabulated function. Small auxiliary tables, called "proportional parts," are often printed in the margin, which relieve the computer from the labor of estimating corrections, by giving the appropriate fractional parts of such tabular differences as occur on the same page of the tables. We can also use interpolation in finding a number from its logarithm, or an angle from its cosine, etc.: we have only to observe that the corresponding corrections to the argument and its function are the same fraction of the tabular interval and the tabular difference.

4. While mathematical tables differ somewhat in arrangement, the same general method of interpolating is applicable to all.

(1) Find two adjacent arguments between which lies the argument sought.

(2) Ascertain the tabular interval by finding the difference between these arguments.

(3) Find the tabular difference by finding the difference between the corresponding functions.

(4) Find what fractional part of the tabular interval separates the argument sought from the first of these two arguments.

(5) Find the same fractional part of the tabular difference.

(6) Increase or decrease by this amount the first of the two adjacent functions, whichever gives a result intermediate between them.

5. In using an unfamiliar table, the computer should observe whether the function increases with its argument, or decreases, so as to know whether to add or subtract the correction. He should also observe whether the tabular differences are "regular," that is, whether consecutive differences are equal. When the tabular differences are irregular, as for the log. sine of a very small angle, the uncertainty of an interpolated result does not exceed the difference between consecutive tabular differences. In any case of doubt as to how to interpolate, or as to the degree of accuracy of the result, the thing to be remembered is that the whole theory of the process grows out of the idea of proportionate increase of argument and function.

(Referred to in §§ 155, 162, 165, 168, 175, 176, 177, 180, 182, 208, 292.)

VIII

Theory of Linear Dependence

(The introductory paragraph from an article in *Annals of Mathematics*, January, 1901, by M. Bôcher.)

The subject treated in the following pages is not only one which, owing to its numerous applications, is of considerable importance, but, while distinctly elementary, illustrates well one of the most striking tendencies of modern algebraic and analytic work, namely, the tendency not to be satisfied with results which are merely true "in general," *i.e.* with more or less numerous exceptions, but to strive for theorems which are *always* true.[1] For these reasons, and because, so far as I know, no adequate treatment of the subject as a whole exists, I venture to offer the following presentation to the readers of the *Annals*.

[1] The great importance of this tendency will be apparent if we remember that when we apply a theorem, it is usually to a special case. If we know merely that the theorem is true "in general," we must first consider whether the special case to which we wish to apply it is not one of the exceptional cases where the theorem fails.

(Referred to in §§ 163 and 191.)

2 SHEETS—SHEET 1.

FIG. 1.

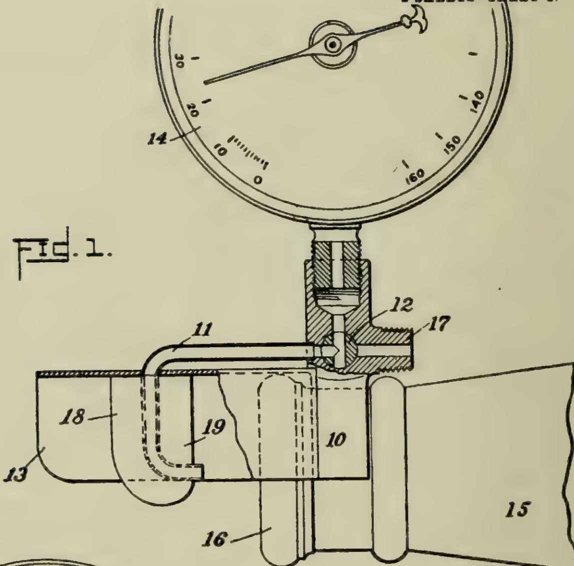
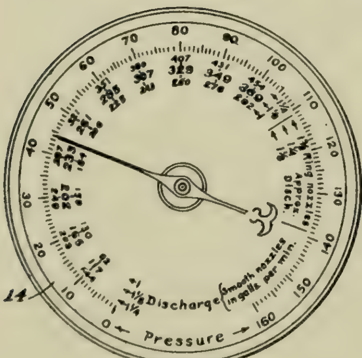
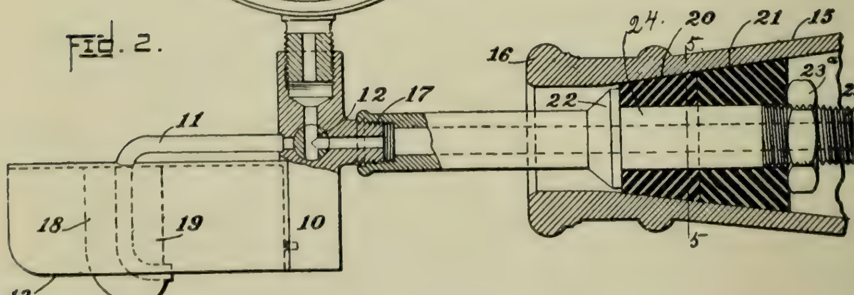


FIG. 2.

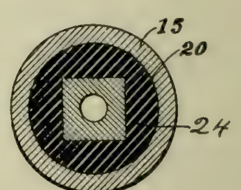


FIG. 5.

IX

(An introductory paragraph from "Contracts in Engineering," by James Irwin Tucker, B.S., LL.B.)

The writer has found his preparation for the present task in some fourteen years of the study, practice, and teaching of civil engineering. The pursuit of a law course in the Boston Evening Law School, coupled with contemporaneous teaching in Tufts College, has made a combination highly stimulating, and withal highly laborious. Of its effectiveness, the present work will speak. In 1908 he was asked to give the course in Contracts and Specifications, and in conducting this class much of the present material was prepared. This experience was of great value, since it indicated the limits of the ordinary student's information upon the subject matter, — it also proved his keen interest in it. The experience also indicated fairly well what could be done in the time generally available for this subject in most engineering schools.

(Referred to in § 163.)

X

Nozzle-piezometer

No. 852,581. Specification of Letters Patent. Patented May 7, 1907. (Printed with the permission of the patentee.)

To all whom it may concern:

Be it known that I, Frank B. Sanborn, a citizen of the United States, and a resident of Cambridge, in the county of Middlesex and State of Massachusetts, have invented a new and Improved Nozzle-piezometer, of which the following is a specification.

My invention relates to devices for determining fluid pressures and more particularly the pressure of water or force of streams flowing from nozzles, and the static pressure existing in pipes. Its principal objects are to provide a device that will be light enough to be carried conveniently in the pocket, of simple design so that it can be quickly applied to a flowing stream and, with a pressure gage or indicating means attached, show the full available pressure afforded by the flowing stream, and also show the quantity of water thus being delivered. Furthermore

the application of the device to the flowing stream should easily be accomplished even by one unskilled and even without liability of getting wet by the broken streams of water or other fluid. An additional object of the invention is to afford a convenient means of determining the static pressure at any hydrant or the like. These objects are attained by the apparatus represented in the following drawings and hereafter described.

Figure 1 is a longitudinal sectional elevation of one embodiment of my invention applied with a pressure gage or indicating means to a nozzle for measuring dynamic pressure. Figure 2 is a longitudinal sectional elevation of another embodiment of my invention applied to a nozzle for measuring static pressure. Figure 3 is a top plan view of the device illustrated in Fig. 1 with the gage removed. Figure 4 is an end elevation looking from the left-hand face of Fig. 1, the nozzle being omitted. Figure 5 is a transverse sectional detail on the line 55 of Fig. 2.

The body portion or supporting member 10 of the device is shown in Figs. 1 and 2. Associated with this body portion is the bent tube 11, the three-way cock 12, the shield 13, and the gage or indicating means 14. The body portion serves as a support for the gage and for the weight that may be superimposed. Also it serves to form a shoulder which is placed in contact with the bead 16 of the nozzle, and this contact, together with a slight pressure from the hand keeps the piezometer in place and helps to keep the proper alinement. The bent tube 11 has the form approximately as shown in Figs. 1 and 2. The water from the nozzle 15 enters this tube and transmits the desired pressure to the pressure gage or indicating means 14. At 12 is a three-way cock which permits (1) the passage from tube to gage to be open, or (2) the passage from tube to connection 17 to be open, or (3) the passage from connection 17 to pressure gage to be open.

The curved shield 13 by its contact with the bead 16 and the stream issuing from the nozzle resists movement to one side or another. This shield also prevents water from issuing upward or backward. Similarly to keep alinement and prevent splashing are the knife edges or dividers 18 and 19. The thickness of these knife-edges or dividers increases from the edges 18 and 19 to the full size of the bent tube. Thus it gives a smooth passage for the water as it comes on at 19 and flows off at 18.

The gage or indicating means 14, has special graduations, which permits both the pressures and the quantity of discharge

FIG. 3.

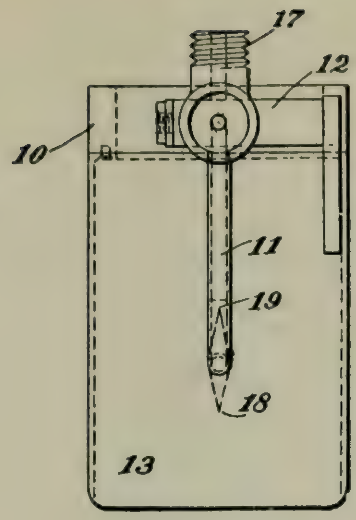
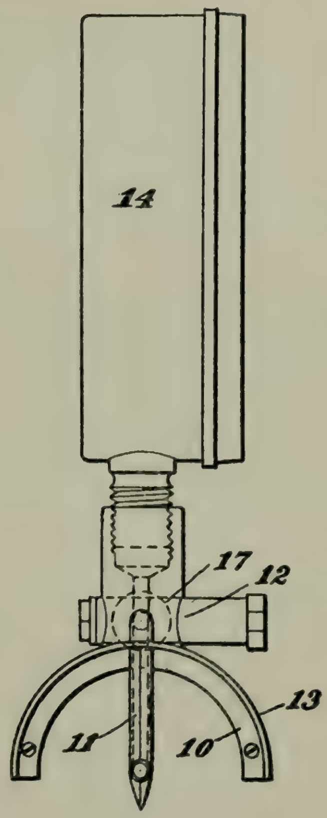


FIG. 4.



to be indicated. There are four concentric rows of figures on the dial face; one row represents pressures, and the other three rows represent the discharges by different sizes of nozzles for corresponding pressures obtained by applying the nozzle piezometer to one of the sizes of nozzles represented.

17 is a connection with outside thread for the apparatus shown in Fig. 2. In this position the apparatus is in use for testing static pressure. Rubber or yieldable bushings 20 and 21 — one or both being used according to the size of nozzle that is available — taper gradually to conform to the bore of the nozzle, and they fit closely on a metal pipe. Back of these rubber or yieldable bushings is nut 23^a which coöperates with the thread 23 and prevents the pipe from being displaced by the pressure of the fluid as it enters the nozzle, and forces through the three-way cock which is set as shown in Fig. 2 so that the fluid pressure acts upon the gage which thus indicates the true static pressure.

22 is a shoulder which acts when the apparatus needs to be driven out of the nozzle after a test is finished.

23 is a taper-threaded connection usually with $\frac{1}{8}$- or $\frac{1}{4}$-inch pipe thread which enables the apparatus to be applied to a hole fitted with a corresponding thread as for instance in a hydrant. Pressure is thus obtained without the use of a nozzle.

In order conveniently to screw the apparatus into place and unscrew it after a test is completed the hole through the bushings and portion 24 are made with square or angular cross-section, thus permitting the bushings to be gripped with the hand and the whole turned without the aid of a wrench.

Thus it is seen that the whole apparatus serves (1) to obtain quickly the effective pressure of fluids flowing through a nozzle, (2) likewise even the quantity of discharge for certain sizes of nozzles, (3) the static pressure of fluids by inserting a portion of the device in a nozzle, or (4) the static pressure by application to a tapped hole.

Having thus described my invention, I claim as new and desire to secure by Letters Patent: —

1. A testing apparatus for use in connection with a fluid-discharge device comprising indicating means and portions applicable to the discharge device and having passages leading to the indicating means, said passages being maintained in different relations to the discharge device according to which one of the portions of the apparatus is applied to the discharge

device whereby fluid pressures of different characters may be measured.

2. A testing apparatus for use in connection with a fluid-discharge device comprising indicating means, a body portion having passages leading to the indicating means, means for holding the body portion with the inlet-opening of one passage within the discharge device, and means for positioning said body portion with the inlet-opening of another passage opposite the open end of the discharge device.

3. A testing apparatus for use in connection with a fluid-discharge device comprising indicating means, a body portion having passages leading to the indicating means, means for confining the fluid at the discharge device to one passage, and means for positioning the body portion with the inlet-opening of a passage opposite the open end of the discharge device.

4. A testing apparatus for use in connection with the discharge nozzles or the like comprising indicating means to which lead a plurality of passages, means associated with one passage for closing the nozzle to direct fluid pressure into said passage, and means for fixing the relation of the opening of another passage with respect to the nozzle.

5. A testing device for use in connection with discharge nozzles or the like comprising indicating means having a passage leading thereto, means for positioning the inlet-opening of the passage at a point removed from the nozzle, whereby free fluid flow from said nozzle is permitted, and a shield extending over both the extremity of the nozzle and the inlet-opening of the passage.

6. A testing apparatus for use in connection with discharge-nozzles or the like comprising indicating means having a passage leading thereto, means for fixing the relation of the inlet-opening of the passage to the open end of the nozzle, and a shield extending over both the extremity of the nozzle and the inlet-opening of the passage and being curved over the stream issuing from the nozzle.

7. A testing apparatus for use in connection with discharge-nozzles or the like comprising indicating means having a passage leading thereto, means for fixing the relation of the inlet-opening of the passage to the open end of the nozzle, and a divider situated adjacent to the inlet-opening of the passage and having a reduced edge turned toward the nozzle.

8. A testing apparatus comprising a body portion, a tube extending outwardly from, and then back toward said body portion, and a gage connected with the tube through the body portion.

9. A testing apparatus comprising a body portion adapted to engage the exterior of a nozzle, a tube extending outwardly from said body portion, and having an enlargement adapted to be received by and to close the interior of said nozzle and a gage connected with the tube through the body portion.

10. A testing apparatus comprising a body portion, a tube extending outwardly from said body portion, a sectional bushing of yieldable material surrounding the tube, and a gage connected with the tube through the body portion.

11. A testing apparatus comprising a body portion, a tube extending outwardly from said body portion, a sectional bushing of yieldable material surrounding the tube, means for preventing the rotation of the bushing on the tube, and a gage connected with the tube through the body portion.

12. A portable testing apparatus comprising a body provided with an indicator-passage and separate inlet-passages communicating with the indicator-passage, a valve operable in the body for independently connecting either inlet-passage with the indicator-passage, means for applying static fluid pressure to one of the inlet-passages, and means for applying dynamic fluid pressure to another inlet-passage.

13. A portable testing apparatus comprising a body provided with an indicator-passage and separate inlet-passages communicating with the indicator-passage, means for applying static fluid pressure to one of the inlet-passages, means for applying dynamic fluid pressure to another inlet-passage, and a shield extending from the body over the dynamic-pressure-applying means.

14. A portable testing apparatus comprising a body provided with an indicator-passage and separate inlet-passages communicating with the indicator-passage, means for applying the static fluid pressure to one of the inlet-passages, means for applying dynamic fluid pressure to another inlet-passage, and a shield extending from the body over the dynamic-pressure-applying means and at the side toward the indicator-passage.

15. A portable testing apparatus comprising a body provided with an indicator-passage and an inlet-passage and having a supporting-portion adapted to engage a nozzle, and a

conduit leading from the inlet-passage and opening toward the supporting-portion.

16. A testing apparatus for use in connection with a fluid-discharge device comprising portions applicable to the discharge device and having passages maintained in different relations to said device by the contact of the apparatus therewith, and a gage to which the passages lead and which is provided with a plurality of scales, including one indicating fluid pressure and one indicating the quantity of fluid discharged.

17. A portable testing apparatus comprising a body provided with an indicator-passage and an inlet-passage and having a supporting-portion adapted to engage a nozzle, a conduit leading from the inlet-passage and opening toward the supporting-portion, and a shield extending over the conduit-opening.

18. A portable testing apparatus comprising a body provided with an indicator-passage and an inlet-passage and having a curved supporting-portion, a conduit leading from the inlet-passage and opening toward said supporting-portion, and a shield extending from and generally conforming to the curve of the supporting-portion and projecting over the conduit-opening.

19. A portable testing apparatus comprising a body provided with an indicator-passage and an inlet-passage and having a supporting-portion, a conduit leading from the inlet-passage, and a divider situated adjacent to the conduit and having a reduced edge extending toward the supporting-portion.

20. A portable testing apparatus comprising a body provided with an indicator-passage and an inlet-passage and having a supporting-portion, a conduit leading from the inlet-passage, and a divider extending upon opposite sides of the conduit and having its outer edges reduced, one of said edges being upon the side toward the supporting-portion.

Signed by me at Boston, Massachusetts, this 21st day of September, 1905.

Frank B. Sanborn.

Witnesses:

C. H. Phinney,

Gardner C. Anthony.

(Referred to in §§ 174, 183, 223, 228, 230, 264, 288.)

XI

Color Photography

(From *American Review of Reviews*, February 19, 1908. Printed with the permission of the *Review of Reviews*.)

1. It is known that the Lumière system of color photography depends for its success upon the fact that the innumerable hues of nature may in reality be looked on as combinations of the three fundamental colors, — red, blue, and green. In addition, dependence is put upon the circumstance that in order to get a composite effect, say purple, it is not necessary that the two colors, red and blue, be each made to cover the entire surface of the object. It is sufficient if the objects be thoroughly well sprinkled with innumerable fine red and blue dots, each color being evenly distributed. To secure the precise shade of purple desired, exactly the right proportion of red and blue dots must be combined. The decision as to such combination is not left to the photographer, but is automatically effected by nature herself. This becomes clear in the explanation of the process given by Dr. M. W. Meyer in a recent number of *Ueber Land und Meer*.

2. To form the sensitive plate the glass is first covered with a layer of very fine grains of starch (potato flour). These grains are of excessive minuteness, — about eighty million being required to cover the surface of three and one-half by four and five-eighths inches. These grains have first been saturated in a color dye, the colors being the three fundamental ones. The glass plate is then covered with a mixture of equal quantities of the three colors. Such a plate will then appear colorless, — or should do so. We have now an approximately even mixture of those colors necessary to produce any natural hue. Bromide of silver, so prepared as to be equally sensitive to all three colors, is now poured over the layer of starch grains, and the sensitive plate is done.

3. The ordinary camera may be used. One attachment, and but one, is required. This is a "yellow plate," the object of whose use is to correct the arrangement of the modern camera whereby the object-glass focuses the ultra-violet rays upon the sensitive plate. The reason for this in ordinary photography is that such rays affect more decidedly the photographic plate than those which reproduce to the eye the colors of nature.

But, for the purposes of color photography, the spectral colors themselves are desired. The "yellow plate" it is necessary shall be specially adapted to the peculiar Lumière sensitive plate. It is said, on the other hand, to be suited to the optical arrangement of any modern camera.

4. The Lumière plate is introduced into the camera with the glass side toward the object glass. We are now ready for color photography. In practice it is found necessary to make longer exposures than with the ordinary photographic process. There are two reasons for this: First, we have given up the ultra-violet rays for the rays which express nature more truly, but which are chemically weaker; second, as the object is to affect the bromide of silver, the rays of light must now pass through the starch coating, and so are weakened.

5. We will now suppose that a many-colored landscape has been properly focused on our plate. The red rays from a red object fall upon the plate, pass through the glass, and fall upon the grains of starch. If the object is a chimney, this chimney will be imaged on the side of the starch coating next the glass. This image will contain within its limits grains of all three fundamental colors. The grains of any one color, or of any combination, would yield an image of the chimney. However, the red rays, imaging the chimney, fall some of them upon red grains of starch, others upon grains of starch which are not red. The former pass through and affect the coating of bromide of silver; the latter are arrested and lost. In the case of a purple object, both red and blue rays succeed in passing through the starch layer and working upon the bromide of silver. And so on, with the various colors and color combinations.

6. It must still be confessed that we do not have any vestige of colored images on our plate. However, the plate is now taken into a dark room. This must be a genuine dark room, as light of any color would have disastrous results. Any one of the usual developers can be used. Metallic silver is now deposited wherever the bromide of silver has been affected by the light. The result of this is to produce a negative having the general appearance of that produced in the ordinary way. No colors yet. Now there is a particular chemical which is a solvent of metallic silver but not of the bromide of silver. Our negative is now introduced into a bath of this preparation. The metallic silver, covering precisely those places affected by the light transmitted through the starch coating, is now dissolved away,

and the bromide of silver where the light did not succeed in getting through is left unaffected. The effect of this removal of the silver is to display the colors of the starch. Red grains appear picturing the form of the chimney. Red grains now also come to light showing the image of the purple object. But, associated with these red grains, are blue ones also appearing and displaying the form of the purple object. The eye will receive both a red and a blue image, the separate elements of which are so mingled and so minute that the two are blended into one purple object, precisely as in nature. And so with various objects of all colors and combinations of colors.

7. In bright daylight the plate is put into another bath where black silver is now deposited upon precisely those points where the bromide of silver has so far remained intact. But such points are those which in nature were dark, and so sent no light of any color through the glass plate and starch coating to affect the layer of bromide of silver. The effect of this deposition of black silver is to darken the parts of our plate corresponding to the dark spots of the landscape. We have now, — not a negative, — but a diapositive whose colors and shadings correspond to those of nature. This ends the essential process, although the plate is passed through several other baths to perfect results.

(Referred to in §§ 155, 158, 161, 164, 167, 172, 175, 177, 179, 181, 200.)

XII

Multiplex Telephony

(From *The Outlook*, February 11, 1911. Printed with the permission of *The Outlook*.)

In these days, when the Patent Office is accused of being "a mother of trusts," and some patents have brought millions to inventors and have created monopolies for great corporations, it is refreshing to find an inventor so generous and public-spirited that he will give to the world the results of his discovery without money and without price. Such a man is Major George Owen Squier, of the United States Signal Corps, who, having received patents fully protecting him in a valuable discovery in the field of wireless electrical communication, has refused to profit by his invention and has dedicated it freely to the service of his fellow men. Some years ago the multiplex telegraph was

perfected, by means of which a number of telegrams can be sent simultaneously over the same wire. This is effected by the introduction of tuning forks into the circuit at the sending point, duplicated as to pitch at the receiving end. It is now more or less possible also to "tune" or synchronize the wireless telegraph message so that it will be received only by an instrument in tune with the sending apparatus. It is usually a surprise to the uninitiated to learn how slight need be the current to transmit successfully a message by a submarine cable. The current employed on the Atlantic cables could be generated in batteries the cells of which were not much larger than thimbles, and the current used to transmit speech over a telephone wire is almost equally feeble. This necessarily feeble current must be revivified every few miles to permit of long-distance conversation. On the other hand, the electric energy necessary to send a wireless message is enormous. The earth probably acts as a great electrical dynamo; revolving upon its axis, it generates electrical currents by its revolution. The surrounding atmosphere is thus charged with electricity which is usually in a state of equilibrium. To send through the air an electrical impulse which can be perceived at a distance requires that the generating force shall be so great as to create a disturbance of this equilibrium. Radiating from its point of origin, the impulse proceeds in electrical waves equally in all directions, just as do the ripples when a stone is thrown into a pond. While it has been found possible, as stated above, to arrange so that wireless messages, under favorable conditions, can be received intelligently only through apparatus specially in tune with the sending point, it has not hitherto been possible to prevent the waves from radiating in all directions, and this has been the drawback in wireless telephony. Electrical waves, like those produced in water or in air or in solid matter by a blow or by a sound, are measured by the amplitude of their oscillations and wave lengths. The oscillations of the air wave produced by a large organ pipe are comparatively large and slow, while those produced by a smaller pipe are comparatively small, rapid, and short. Major Squier's discovery was that by reducing the frequency of oscillation he could direct the electric impulse along a wire which serves as a guide. The current transmitting speech or the impulse of the electric telegraph travels either in or upon the surface of the wire conductor, depending upon the character and strength of the battery or other generator. The impulse

carrying abroad the message of wireless transmission travels by wave advancement through the atmosphere. Major Squier found that by limiting the speed or amplitude of oscillation he could impart wireless impulses to the layer of ether immediately surrounding a wire, and by "tuning" them could enable a number of conversations to be carried on at the same time, without interference with each other. The wire is essential, but only to serve as a guide for the wireless form of electrical transmission. It seems probable that the use of the wire guide as a direct conductor of single, or even multiplex, telegraphy, as heretofore, will not interfere with its use for simultaneous multiplex telephony, now rendered possible by this invention. The means by which the inventor accomplishes these results are a little too technical for description in our columns, but it may be said that he employs no new and untried devices; rather a novel juxtaposition and application of well-proven apparatus and methods. This generous gift to the American people should tend in time greatly to lessen the cost of the telephone and materially to increase its convenience.

(Referred to in §§ 162, 164, 169, 172, 175, 196, 197, 198, 200, 223, 228.)

XIII

Major Squier's Multiplex Telephony System

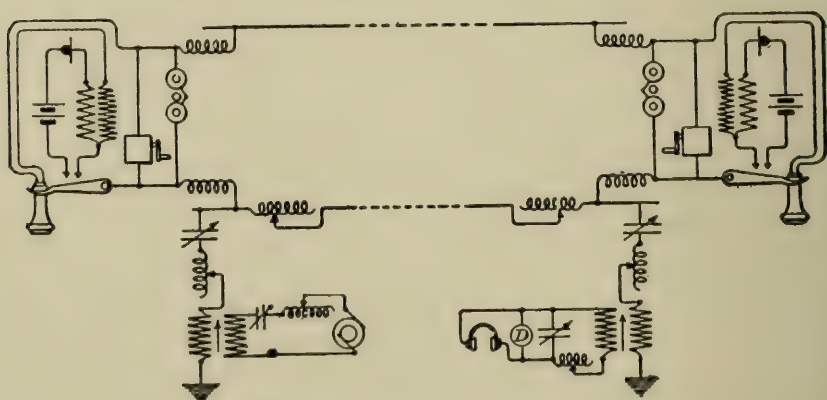
(From *Electrical World*, February 9, 1911. Printed with the permission of the *Electrical World*.)

1. The common conception of the value of a patent is undoubtedly based upon the protection it affords the patentee. Therefore, a patent obtained by an inventor to protect the public against possible claims of other inventors is noteworthy. Furthermore, when the disclosure of the patent, or in this case patents, is remarkable, they are bound to receive liberal attention.

2. Such has been the case with the four patents recently issued to Major George Owen Squier, of the United States Army, previously mentioned in these pages, which are dedicated to the public and which describe his inventions in multiplex telephony. According to Major Squier's system, there may be superimposed upon the ordinary telephone line carrying on ordinary telephone conversation, one or more telephone or telegraph currents, all maintained individual and non-interfering.

This is made possible by the use of an exaggerated skin effect, brought about by the use of oscillating currents with frequencies lying between twenty thousand cycles and one hundred thousand cycles per second. Currents of such high frequencies are beyond the range of the human ear, and yet they will follow exactly the course of an electrical conductor of the caliber of the usual telephone line. They will not traverse the coils usually included in telephone circuits, but they will, on the other hand, readily affect condensers so small as to be of no effect on ordinary telephone currents.

3. Therefore, it will be understood at once that these currents may be led to or from the telephone wire through small condensers without a path being formed sufficient to introduce audible disturbances. As a primary factor in the isolation or selection of any particular oscillating current, the receiving circuit must be turned to resonance for that frequency. Such a circuit will practically reject other frequencies. It is thus easy to introduce upon the line and take off and isolate a number of simultaneously transmitted currents. The next step is that of introducing a current variation in the oscillating current corresponding to voice waves and the reconversion of this variation into sound waves in the receiving circuit.



Multiplex Telephony and Telegraphy.

4. An ordinary telephone transmitter associated with the high-frequency generating apparatus serves to introduce the voice variation, while an integrating detector in the receiving circuit, properly associated with the necessary battery and a telephone receiver serves for the reconversion to sound waves.

5. Major Squier's claim covers many variations of details of his general invention, including series and parallel application and metallic and grounded circuits, etc. It will suffice, however, to show a diagram of one arrangement. The accompanying illustration shows such a diagram, *D*, representing the detector and necessary associated devices.

(Referred to in §§ 158, 170, 175, 223, 228, 229.)

XIV

M. Bleriot's Flight over the English Channel

(As reported in *The Outlook*, August 7, 1909. Printed with the permission of *The Outlook*.)

As soon as I am over the cliff I reduce speed. There is now no need to force the engine. I begin my flight steady and sure toward the coast of England. I have no apprehensions, no sensations — *pas du tout* — not at all. The Escopette [a French torpedo boat assigned by the Government to follow M. Bleriot as a precaution in case of accident] has seen me. She is driving ahead at full speed. She makes perhaps twenty-six miles an hour. What matters it? I am making at least forty-two miles an hour. . . . Ten minutes are gone. I have passed the destroyer, and I turn my head to see whether I am proceeding in the right direction. I am amazed. There is nothing to be seen — neither the torpedo boat destroyer, nor France, nor England. I am alone. I can see nothing at all. . . . I fly westward and reach Shakespeare Cliff. I see an opening in the cliff. . . . Once more I turn my aeroplane, and, describing a half circle, I enter the opening and find myself again over dry land. . . . At once I stop my motor. . . . In two or three seconds I am safe upon your shore. Soldiers in khaki run up, and policemen. Two of my compatriots are on the spot. They kiss my cheeks. The conclusion of my flight overwhelms me. Thus ended my flight across the Channel, a flight which could easily be done again. Shall I do it? I think not. I have promised my wife that after a race for which I have already entered I will fly no more.

(Referred to in § 225.)

XV

A New Separator for the Removal of Slate from Coal [1]

By V. H. Wilson

(From the *Engineering News*, April 7, 1910. Printed with the permission of the *Engineering News*.)

1. The chief objects sought in designing the separator to be described were the avoidance of all impacts and the consequent wasteful chipping of the coal, the doing away as far as possible with hand picking, the removing of flat slate without wasting the flat coal, the exposing of the operation to view so that the exact action of the machine could be observed at all times at a glance, and finally the possibilities of adjusting the machine while in operation.

2. A traveling separating belt, mounted on two shafts, is made to move upwardly on its upper run by means of the drive pulley. The belt, made of metal slats attached to a specially designed link belt, is inclined forwardly as well as transversely, and at such angles as are suitable for the proper separation of the material to be treated. Its transverse inclination is adjustable, while running, by means of a lever and ratchet wheel.

3. The material is fed in a continuous stream upon a pan at the farther and higher end of the machine through a properly constructed feed chute. As it slides off the pan, the upwardly moving belt immediately spreads the material out into a well-spaced stream, so that the coal may slide down against the guide and off at the lower right hand corner of the machine, while the slate, adhering to the belt, is carried upwardly to the left hand side and thus out of the moving stream of coal.

4. The coal is conveyed away from the machine in any desired direction by a suitable chute, and the slate in like manner is collected along the slate apron at the left in a similar chute and disposed of as desired.

5. The capacity of the machine, which varies somewhat with the nature of the material, but chiefly with the size of the coal, ranges from five tons per hour on pea size to 25 tons per hour on steamboat size. The operation is distinctly open to view.

6. The saving by preventing the loss in chippings, which loss

[1] Abstract of an article in *The Yale Scientific Monthly* for March, 1910.

ranges in other separators from 5 per cent to 20 per cent of the coal treated, is enormous. The chippings on this new separator amount, on an average, to less than 0.5 per cent. On the low basis of 5 per cent saved, the amount would be $18,750 on every one hundred thousand tons of prepared sizes shipped. One installation of ten machines, now in operation for more than a year, shows a gain of 10.5 per cent in the prepared sizes, with an output of eleven thousand five hundred tons per month, or a gain of $4.52 per month. In addition to the gain by the prevention of chippings, a saving in labor of $500 per month has been affected.

7. It is not possible in all cases to do away with hand picking by the use of the separator because of the occasional presence of pieces of slate having coal faces and pieces of coal having slate faces.

8. The equipment pays for itself in from ten to eighty days. In treating such material as has been described in connection with the jig, it has been found most effective to use a three-stage process. The first stage has a set of three separators, turning direct to the pocket, without appreciable loss from chippings, 60 per cent to 75 per cent of the total coal in the material, which includes all the glassy fractured cubical coal and all of the flat coal not having slate faces. The second stage has likewise a set of three separators so adjusted as to remove all the flat slate and all the pure slate and rock. With the foregoing mixture or forms trimmed, so to speak, in this way, we have left flat coal with slate faces. Passing this product, which contains only from 25 per cent to 40 per cent of the total coal, to a jig as the third process, a very satisfactory separation can be made.

9. By this three-stage process the losses have been reduced to a minimum, or, to put it the other way, the gains, as shown in the installation of the ten machines previously mentioned, have been as high as 19.5 per cent in the prepared sizes.

(Referred to in §§ 160, 169, 172, 180, 223, 228.)

XVI

The Most Economical Type of Vessel for Navigating Western Rivers

(From the *Engineering News*, May 5, 1910. Printed with the permission of the *Engineering News*.)

1. In connection with the current agitation for the improvement of inland waterways, one of the most important questions relates to the type of vessel to be used upon these waterways. We are fortunate in being able to present to our readers in this issue a discussion of the design of steamboats for use on Western rivers which has been prepared by one of the most competent engineers in this field. The author of the paper, Mr. John M. Sweeney, M. Am. Soc. M. E., of Chicago, has built more than two hundred steam vessels for use on the Mississippi and its tributaries, and has had many years of experience in the peculiar conditions which have to be met in the navigation of these streams. This is a subject on which comparatively few engineers possess information, and on which little that is valuable is to be found on record in engineering literature.

2. Too many engineers have without sufficient thought accepted the idea that depth of channel is an important element for economy in river navigation just as it is in the navigation of the ocean or the Great Lakes. It is this idea that forms the basis for the popular agitation for "deep waterways."

3. The careful reader of Mr. Sweeney's paper will perceive, we are sure, the great advantages for river navigation in swift currents of the shallow-draft vessel, drawing 6 to 8 feet, compared with the deep-draft vessel drawing, say, 15 to 20 feet.

4. One great advantage of the shallow-draft vessel, carrying its load upon a broad, flat deck, is the convenience and economy with which it can be loaded and unloaded. Either merchandise or bulk freight can be quickly and easily placed upon a flat, broad deck, and can be readily reached for unloading. With a deep-draft vessel, on the other hand, such as the typical lake or ocean steamer, the freight must all be lowered into a deep hold by derricks on the ship or the wharf.

5. It is true that where certain bulk freights, like ore or coal, are handled in great quantity, mechanical methods of loading and unloading can be adopted; and the cost of stowing freight into and hoisting it out of deep holds can be greatly reduced.

But there are only a few traffic routes where the business is large enough to make the use of such mechanical methods of loading and unloading profitable. The fact remains, therefore, that for all ordinary freight, and for bulk freight where the business is not of great volume, the vessel carrying its load on a broad, flat deck is far superior to the vessel with deep hold. Of course for navigating the stormy waters of the ocean or the Great Lakes the vessel must have its lading protected by the solid walls of the hull at the sides and a solid deck above. No such necessity exists in the navigation of inland rivers, hence the vessel carrying its load on a broad, flat deck — the typical river steamboat — is not only far less costly to build than the deep-draft ocean vessel, but far less costly to load and unload.

6. There is another reason why the shallow-draft vessel is better by far for river navigation than the narrow, deep-hulled vessel used on the ocean or the Great Lakes. And it is this reason on which particular emphasis is laid in Mr. Sweeney's paper. Mr. Sweeney shows the stern-wheel flat-bottom steamboat to be superior to all other types of vessel for the navigation of our Western rivers, because of its enormous steering power. Some of the advocates of the Lakes-to-the-Gulf deep waterway scheme claim that if the Mississippi River had fourteen feet depth of water available for navigation from St. Louis southward at its lowest stage, there would then be sufficient depth at ordinary stages so that ocean steamships could ascend the river from New Orleans and land their cargo at the wharves of St. Louis. If any of our readers are favorably impressed with this proposal, we suggest a careful comparison of the steering power of the stern-wheel flat-bottom steamboat, such as Mr. Sweeney describes, and that of the ordinary ocean-going vessel. In order to ascend or descend the Mississippi or any of its chief tributaries, a vessel must be able to stem a considerable current, and to do this great steering power is just as necessary as great propelling power.

7. In river navigation, a vessel must be able to keep its course in narrow channels, where a swift current is flowing. The river boat, with its large rudder, shallow draft, and flat bottom, can do this; but the ocean vessel, with its deep, narrow hull and small rudder, when traversing a narrow channel always tends to swing out of its course toward one side or the other, and this tendency is particularly strong if there is any opposing current in the channel.

8. It is not at all difficult to understand why the ocean vessel in a narrow channel is so hard to steer. Imagine an ocean vessel traversing a narrow channel — a ship canal, for example. The water which it displaces is piled up at the bow and flows past on either side, and so long as the vessel is kept just in the center of the channel, the pressure of the two streams on the opposite sides of the hull is equal. But as soon as the bow swerves a little toward one side — say the left — the volume of the current on the opposite side and its pressure against the hull are increased, while the pressure against the hull on the opposite side toward which the bow has swerved is diminished. This unbalanced pressure tends to turn the boat still farther out of its course, and the farther it turns, the greater the forces acting to throw it toward the bank.

9. For an object lesson of the difference in the steering power required to guide a flat-bottom vessel and a deep-hulled vessel, take a piece of 2-inch plank and push it up a channel in which a moderate current is flowing. When lying flat on the water the plank may represent a typical river steamboat or barge. When floating on its edge it may represent a deep-hulled vessel.

10. We offer these illustrations merely to make the problem clear to the reader unfamiliar with matters of navigation. To the marine engineer, however, the behavior of a deep-hulled vessel in a narrow channel is a matter of common knowledge. Pilots and ship captains understand perfectly well the difficulty of keeping a ship in a narrow channel, particularly when there is an opposing tidal current. They know very well how persistently a ship tends to run her nose into one bank or the other in traversing any narrow channel. It is this that has caused the Corinth ship canal to remain unused by shipping. It is this as much as the wash of the banks which keeps down the speed of vessels passing through the Suez Canal to about five and a half knots. At low speeds, however, while there is less tendency of the vessel to veer toward the bank, the steering effect of the rudder is correspondingly small. We are informed that vessels in the Eastern trade, which regularly pass through the Suez canal, have holes in the rudder for bolting on an extension to the rudder blade to give greater steering power while passing through the canal.

11. We have thought it worth while to present the above facts, because of their important bearing on such questions as the much discussed one of sea level *vs.* lock canal at Panama, and

of allowable currents in channels traversed by lake or ocean vessels, as well as their bearing on the question of economic draft for river navigation.

12. Surely these facts deserve the careful study and fair consideration of those who are promoting the movement for inland waterway improvement. If river transportation can be carried on as economically with a draft of six or eight or ten feet as with any deeper draft, why should untold millions be spent in the endeavor to procure fourteen or sixteen or eighteen feet on inland rivers?

13. Again, there is a popular impression (based largely on articles published in newspapers and magazines, by writers equipped with that little knowledge that is proverbially so dangerous), that the reason why river traffic in the West has fallen into decay is because the steamboats used there are not of the best design for economical transportation.

14. The argument has been widely used that because river transportation flourishes in Germany, therefore, the German models of river steamboats ought to be copied in the United States. Before such arguments are accepted by engineers, however, surely careful investigation should be made and accurate knowledge should be gained. Mr. Sweeney makes out a strong showing for the present type of Western river steamboat as a thoroughly economical machine for the conditions it has to meet. He speaks with the authority of long experience. We believe his discussion is an important contribution to the literature of waterway transportation.

(Referred to in §§ 158, 163, 168, 197, 198, 218, 228, 229.)

XVII

A Boat Torpedo of Enormous Destructive Power, Carrying its Own Gasoline Engine and Crew

(From the *Engineering News*, March 17, 1910. Printed with the permission of the *Engineering News*.)

1. The most recent development in torpedo boat construction is a new type which is midway between an ordinary torpedo boat and a Whitehead torpedo. It consists of a submarine hull, which contains all the machinery and the explosive charge, suspended beneath a surface hull rendered unsinkable by a series of compartments packed with cellulose. The Naval Appropria-

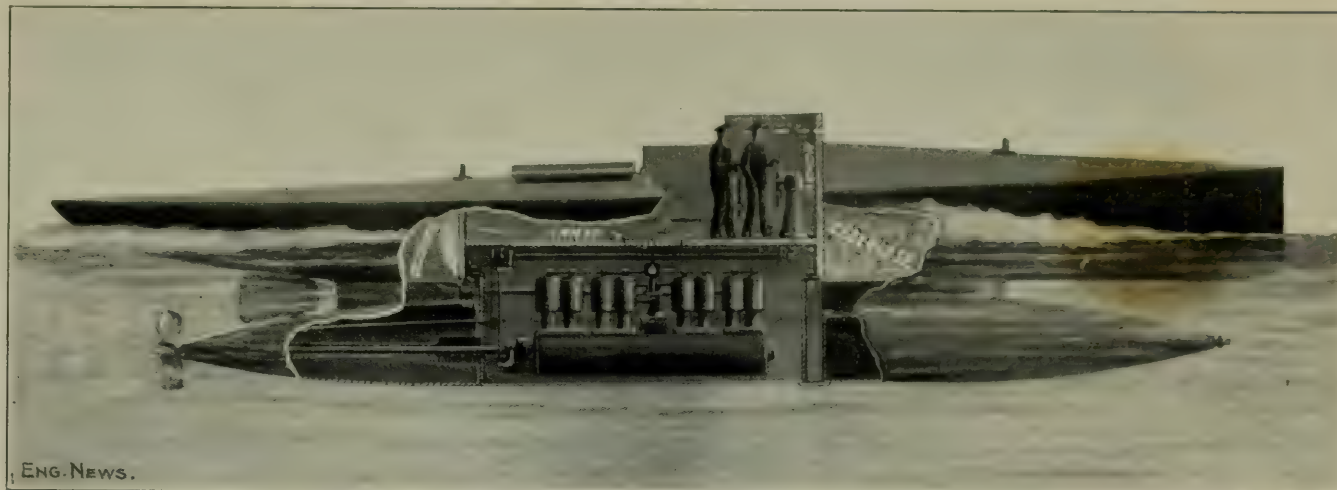
tion Act of 1909 authorized the purchase of this boat for the United States Navy provided it can fulfill requirements in the government tests. These tests are shortly to be made at Boston.

2. The general appearance of the boat torpedo is shown in the accompanying illustration. The submarine portion has the typical cigar shape of the Whitehead torpedo, and contains both the destructive and propulsive equipment. In the forward end is the explosive charge of one thousand pounds of gun cotton, and behind this is the gasoline engine which drives the screw propeller at the stern. The surface hull is shaped like the hull of an ordinary surface boat, and its function is to support the excess weight of the sub-surface hull and to carry the conning tower in which the two operators are stationed. The illustration does not show the boat's true proportions.

3. In operation the boat torpedo is to be navigated by its crew of two men to within what may be considered sure striking distance of the hostile battleship. The helm is then locked, with the prow aimed at the mark, and the engine is set at full speed ahead. The crew of the boat torpedo is expected to abandon it at this juncture in small boats or life buoys. With good luck they may be rescued by friends later. It will relieve those readers who sympathize with the daring crew in this dilemma to learn that possibly an alternative design may be adopted, fitted instead with a submerged bow torpedo tube for discharging an ordinary 18-inch torpedo.

4. There are compelling advantages, however, connected with the design as shown in the illustration. The length of the submerged, or torpedo, hull is about 30 feet, as compared with the 16-foot length of the ordinary 18-inch torpedo. Its larger size gives room for the mammoth charge of one thousand pounds of gun cotton — about eight times the weight of explosive carried by the 18-inch Whitehead type. The eight-cylindered gasoline engine is mounted in the midships portion of the submerged hull, and develops one hundred and fifty horsepower. The engine and rudder are controlled from the conning tower directly above in the surface hull, which communicates through a hatchway with the engine compartment. The rudder is located in the V-shaped space between the sterns of the two hulls.

5. The conning tower is protected by heavy armor, which is also extended over the floor as additional protection to the power plant below. The surface hull itself is 45 feet 9 inches long, with a beam of 5 feet 4 inches. The weight of the entire


Eng. News.

vessel is given as six tons, and its draft as 3 feet 9 inches. The surface hull is protected by cellulose packed within its double walls. This, it is claimed, makes the boat unsinkable and practically immune from serious injury by the comparatively small guns ordinarily relied upon for defense against torpedo attacks. In the illustration, a dotted white line will be found five or six feet back from the surface hull's prow, marking the extent of its soft collapsible nose. Upon striking the side of a ship at good speed, this soft nose crumples up and allows the warhead of the shorter torpedo hull to get into action.

6. The required speed of sixteen knots has been excelled, we are informed, in preliminary trials made by the builders, in which a speed of eighteen knots was attained without difficulty. The cruising radius of the boat torpedo at 10-knot speed is 200 miles, which limits its field of action to the defense of ports and neighboring coast line unless, indeed, small boats of this type be carried on board larger vessels. They could then be launched and used against an enemy's fleet in foreign harbors, or, under favorable weather conditions, in the open sea. The price to be paid for this boat of the size described is $22,500. Provided this first boat is approved in the coming trials, the Navy Department is authorized to contract for one other of the same size and one larger and faster boat of the same type to cost $400,000. The larger boat torpedo will be known as a "sub-surface seagoing destroyer."

7. The present vessel was constructed at a Boston shipyard last year after designs prepared under the direction of Tams, Lemoine, and Crane, consulting naval architects, of New York City. The inventor of this new type of vessel is Mr. Clarence L. Burger of New York City. Mr. Burger received the degree of Civil Engineer from Princeton University in 1885.

(Referred to in §§ 155, 168, 172, 174, 180, 183, 229.)

XVIII

Introduction

(Section 1, from "Elements of Sanitary Engineering," by Mansfield Merriman, (formerly) Professor of Civil Engineering in Lehigh University. Printed with the permission of Professor Merriman.)

1. Sanitary science embraces those principles and methods by which the health of a community is promoted and the spread

of disease is prevented. Hygiene properly relates to the individual or to the family, but sanitary science has a wider scope, and includes the village, the city, and the community at large. Hygiene is the preservation of the health of the individual under the rules of the physician, while sanitary science has for its aim the preservation and protection of the health of the community under the combined action of physicians, engineers, and the civil authorities.

2. The field of sanitary science is a wide one. It includes the collection of vital statistics, and particularly the statistics of mortality and disease, the isolation and quarantine of infectious diseases, the disinfection of houses, the management of hospitals, and the proper burial of the dead. It embraces all the regulations for preventing adulteration of food and pollution of air and water. It treats of the methods of heating and ventilating public buildings so as to promote comfort and health, of the methods for securing pure and abundant supplies of water, of the drainage of land, and of the removal of garbage and sewage. To properly coördinate all these subjects, sanitary science uses the principles of biology, chemistry, medicine, physics, and engineering, and from these it frames regulations to be enforced by the civil authorities. It invokes the science of the biologist and chemist, the experience of the physician, the constructive talent of the engineer, and the authority of the legislature, in order to preserve and protect the health of the community.

3. In this chapter only a small part of the field of sanitary science can be discussed, and the portions to be selected are those which are most directly applicable to the work of the sanitary engineer. The engineer cannot be a biologist or a chemist, but he must be able to understand the main reasons for their conclusions. He cannot be a physician, but he should know something about the general subject of the prevention of disease. He cannot be skilled in architecture, but he should understand the fundamental principles relating to heating and ventilating. He cannot be an expert in social science or in law, but he should not be ignorant of the methods by which vital statistics are collected and sanitary regulations are enforced. This chapter aims to briefly explain some of these subjects, in order that the student may obtain a broad view of the whole field, and that the engineer may be better able to effectively coöperate with the other professions in advancing the sanitary conditions of the community.

4. Civil engineering is the art of economic construction, that is, the art of making structures for the public use at the minimum cost for installation and operation. A person not an engineer may construct a railroad or a water supply system, but its cost will be higher and its efficiency lower than one built by the engineer of experience. The engineer, according to the definition of Telford, utilizes the materials and forces of nature for the benefit of man; but to this should be added that in so doing he aims to secure the least possible cost of construction and maintenance.

5. Sanitary engineering is that branch of civil engineering which is concerned with the constructions for promoting the health of the community. Such constructions fall into two classes, called Water Supply and Sewerage, and these form the subject for the following chapters. A pure and abundant water supply, and an efficient system of sewerage, have been universally found to promote cleanliness and prevent the spread of disease; to construct these in an economic manner is the main work of the sanitary engineer.

(Referred to in §§ 161, 162, 242, 254, 258.)

XIX

Surface Waters

(Section 19, from "Elements of Sanitary Engineering," by Mansfield Merriman. Printed with the permission of Professor Merriman.)

1. Surface waters include those of swamps, brooks, rivers, and lakes, and these differ greatly in regard to their characteristics. Swamp water is liable to be heavily charged with vegetable matter, but the flow in brooks and rivers causes a continuous improvement in quality, and when a lake is reached the purest surface water is found. This improvement in quality is effected in two ways: first, by settling or sedimentation, which removes the suspended matter; and second, by aeration or contact with the air, whereby oxygen is supplied to decompose and destroy both the suspended and the dissolved organic matter.

2. Swamp water usually has a high proportion of vegetable matter in the total solids; and a high proportion of albuminoid ammonia is also found. In boggy and peaty regions this gives a brown color to the water, but it fortunately happens that the vegetable matter is in a permanent state which resists further

decomposition, so that sometimes these waters are noted for their keeping qualities and are well adapted to being taken on long sea voyages. When used for a public water supply, the aeration due to pumping and flow is apt to cause this organic matter to decompose, and hence filtration is necessary. Swamp water has been used at Long Branch, N.J., Norfolk, Va., and other cities without unpleasant results; its softness renders it convenient for washing, but brook or river water is always to be preferred for drinking purposes when it can be had.

3. Brook water consists of the run-off of the surface, of the drainage of swamps, and of percolation from meadow and springy land. It is generally thought that the color and taste of brook water give a reliable indication of quality, but a brook having its source in farmyards or swampy pastures may furnish water which is very unwholesome, even though it be clear and sparkling. With steep slopes and rocky beds purification continually goes on, and if further sources of contamination be absent, good potable water may perhaps be found a mile or two from the suspicious sources. Brook water is soft except when the flow comes from limestone springs, the organic matter is usually lower than in swamp water, while the nitrates are usually higher. It forms a reliable public supply for hundreds of towns, being purified by natural sedimentation in collecting reservoirs and sometimes by artificial filtration.

4. A river is formed by many brooks, and the quality of river water differs mainly from that of brook water in the higher proportion of inorganic matter which has been collected from the soil in the flow. A river having towns upon its banks is liable to become polluted by the drainage and sewage that runs into it, and at present one of the important sanitary problems is how to dispose of the refuse of towns without polluting the streams. In Europe this subject has received much attention, and the matter that may be thrown into rivers is regulated by law; in this country some states have also made enactments which in time will no doubt be perfected and enforced. The chemical analysis of water collected below a town which discharges sewage into a river shows a higher proportion of chlorine than is found above the town, and the number of bacteria will also in general be much greater. River water is improved by sedimentation in reservoirs, but if very impure it must be treated by artificial filtration before delivering it to the distributing basins.

5. Lakes are natural reservoirs which collect the water of brooks and rivers. When of large size they furnish an excellent supply, for both sedimentation and aeration have had opportunity to remove the organic matter. The water of a lake may be polluted, however, by the refuse of towns or by the discharge of sewage into it, so that contamination may extend to a considerable distance from the shores; at Chicago, for instance, the supply is collected in cribs four or five miles from the lake shore and carried in tunnels to the city in order to secure uncontaminated water. In small lakes and ponds the liability to pollution is greater still, and hence filter galleries are frequently used to insure purification.

6. It should be noted that the quality of water from any given stream or lake undergoes systematic variation with the changes of the seasons. In late winter and early spring the melting ice and snow cause the maximum run-off of the year, and the streams become swollen and foul with organic and inorganic matter. In summer the flow becomes normal and the highest degree of purity obtains; in autumn the flow is a minimum, and liability to pollution is greater than in the summer. Even in a pond whose surface does not vary greatly in height there are variations due to the influence of wind and temperature. It was shown by Drown in 1891 that in deep ponds and reservoirs a stagnant layer containing unoxidized organic matter is formed during the summer, and that this rises to the surface late in the fall when the higher layers become cooled; a vertical circulation then occurs with more or less regularity until spring, when the stagnant layer begins to form again. Hence both river and lake waters are liable to be of variable quality from fall until spring, and the necessity for artificial purification is greater then than during the summer season.

(Referred to in §§ 161, 167, 180, 268, 269, 278.)

XX

Evidence in Favor of Wetting a Mine

(From the *Engineering and Mining Journal*, February 18, 1911. Printed with the permission of the *Engineering and Mining Journal*.)

1. Coal-mining engineers and superintendents seem to have arrayed themselves either for or against the plan of wetting a

mine. Those who oppose the system of sprinkling or introducing moisture underground, point to the great loss of lives from falls of roof. Their claim is that the introduction of moisture into the workings causes disintegration of the roof and sides, thus increasing the fatalities due to falls. All information, therefore, bearing on this subject is particularly interesting.

2. One of those who favor the wetting of mines as a means of preventing dust explosions is Mr. Haas, consulting engineer of the Consolidated Coal Company, in West Virginia. Mr. Haas has been introducing moisture into his mines for quite some time, and has been carefully investigating the effect. At most of the mines, the wetting is accomplished through the introduction of steam into the intake air, as well as by the more common system of sprinkling. In no case has there been any indication that the water has affected the roof or sides. Mr. Haas states further: "As you are aware, we have had two gas explosions in two of our mines recently, due to outbursts of gas from gas wells. These mines are two of a large number which we attempted to keep saturated with exhaust steam. The fact that neither of the two explosions propagated beyond the limit of the gas mixture gives us almost conclusive confidence that a wet mine, with saturated humidity of its atmosphere, is safe, so far as the propagation of an explosion is concerned."

(Referred to in §§ 218, 228.)

XXI

(From Chapter I of "The Principles of Psychology," by William James, (formerly) Professor of Psychology in Harvard University.)

1. On the whole, few recent formulas have done more real service of a rough sort in psychology than the Spencerian one that the essence of mental life and of bodily life are one, namely, "the adjustment of inner to outer relations." Such a formula is vagueness incarnate; but because it takes into account the fact that minds inhabit environments which act on them and on which they in turn react; because, in short, it takes mind in the midst of all its concrete relations, it is immensely more fertile than the old-fashioned "rational psychology," which treated the soul as a detached existent, sufficient unto itself, and assumed to consider only its nature and properties. I shall therefore feel free to make any sallies into zoölogy or into pure

nerve physiology which may seem instructive for our purposes, but otherwise shall leave those sciences to the physiologists.

2. Can we state more distinctly still the meaning in which the mental life seems to intervene between impressions made from without upon the body, and reactions of the body upon the outer world again? Let us look at a few facts.

3. If some iron filings be sprinkled on a table and a magnet brought near them, they will fly through the air for a certain distance and stick to its surface. A savage seeing the phenomenon explains it as the result of an attraction or love between the magnet and the filings. But let a card cover the poles of the magnet, and the filings will press forever against its surface without its ever occurring to them to pass around its sides and thus come into more direct contact with the object of their love. Blow bubbles through a tube into the bottom of a pail of water, they will rise to the surface and mingle with the air. Their action may again be poetically interpreted as due to a longing to recombine with the mother atmosphere above the surface. But if you invert a jar full of water over the pail, they will rise and remain lodged beneath its bottom, shut in from the outer air, although a slight deflection from their course at the outset, or a re-descent towards the rim of the jar when they found their upward course impeded, would easily have set them free.

4. If now we pass from such actions as these to those of living things, we notice a striking difference. Romeo wants Juliet as the filings want the magnet; and if no obstacle intervenes he moves towards her by as straight a line as they. But Romeo and Juliet, if a wall be built between them, do not remain idiotically pressing their faces against its opposite sides like the magnet and the filings with the card. Romeo soon finds a circuitous way, by scaling the wall or otherwise, of touching Juliet's lips directly. With the filings the path is fixed; whether it reaches the end depends on accidents. With the lover it is the end which is fixed, the path may be modified indefinitely.

5. Suppose a living frog in the position in which we placed our bubbles of air, namely, at the bottom of a jar of water. The want of breath will soon make him also long to rejoin the mother atmosphere, and he will take the shortest path to his end by swimming straight upwards. But if a jar full of water be inverted over him, he will not, like the bubbles, perpetually press his nose against its unyielding roof, but will restlessly explore the neighborhood until by redescending again he has

discovered a path round its brim to the goal of his desires. Again the fixed end, the varying means!

(Referred to in §§ 208, 265.)

XXII

Internal Electro-magnetic Forces in Lamp Filaments

(From *Electrical World*, February 9, 1911. Printed with the permission of the *Electrical World*.)

1. It is known that magnetic flux density traversing any medium is accompanied by certain mechanical forces in the medium. These forces are of two kinds, namely, first, a tension along the flux paths, and second, a side thrust, or pressure, across the flux paths. In a general way we may liken a group of magnetic lines of flux to a group of stimulated fibers in the muscles of an animal. When the muscle contracts, it exerts a tension along its fibers which tends to shorten the muscle, and it also exerts a pressure across its fibers which tends to swell the muscle. When an athlete proudly exhibits the highly developed condition of his biceps, he usually draws attention to the repulsive forces, or to the lateral swelling of the fibers on voluntary stimulation; but, of course, the tension forces, acting in leverage on his forearm, might also be brought in evidence. To express the facts in another way, magnetic flux paths, like stimulated muscle fibers, tend to shorten themselves along their axes and to spread apart or repel each other at right angles thereto. Uniform magnetic flux travels in parallel straight lines. Its tension is exerted along these lines. Its side thrust is not so evident, but the fact that the flux paths remain parallel and do not bulge apart shows that a lateral pressure from outside squeezes them together and holds the repulsive tendency in check.

2. It has also been shown that in the space outside of a conductor these forces are always in static equilibrium on matter unless the space is occupied by substances of different magnetic susceptibility. Thus, if the space outside a coil of active wire contains both air and iron, forces will, in general, be set up tending to alter the disposition of the two materials. There are, in fact, ammeters based upon this principle. But if the space external to the active conductor, or conductors, contains a

medium of uniform magnetic susceptibility, there then will be no resultant forces tending to alter the distribution of the medium. There is no resultant tendency of the air to move within a hollow active coil. Within the substance of an active conductor, however, this mechanical equilibrium disappears, and magnetic forces act upon the substance of the conductor. The tension of the circuit flux around an active straight wire, acting like the tension of stretched rubber bands, tends to squeeze the wire or press inward upon its surface; while the side thrust of the same flux tends to pull the wire apart along its axis — that is, to elongate it.

3. Mr. Carl Hering has investigated these electromagnetic forces in the past, particularly in connection with electric furnaces. Since both the magnetic tension and magnetic pressure per unit area are proportional to the square of the flux density, these forces tend to exhibit themselves most powerfully in the neighborhood of powerful currents, such as furnaces employ. Mr. Hering has shown, in fact, both experimentally and theoretically, that the "pinch" phenomenon, as the tension effect is called, creates an upper limit to the current strength that can be used in electric furnaces. In his article appearing on p. 371 of this number he discusses the magnitude of the electromagnetic forces set up in metallic-filament lamps. The current densities in such filaments are, as he points out, very high — from 230 amp. to 450 amp. per square millimeter of cross section; but the pinch pressure is only about a decigram per square centimeter. This is not a serious pressure, considering that the filament are supported in a vacuous space and have very little other pressure tó resist. Of course, as the article points out, the filament is raised to the softening temperature, and the tension is applied rhythmically in alternating-current service. While bearing the existence of these electromagnetic forces in mind, we should do well to await the results of further researches on the behavior of these rare metals under very high temperatures. It may be that there is some other effect besides the pinch effect present, such as a crystallizing effect. The appearance under the microscope of some tantalum filaments after a long period of service suggests crystalline deformation, or cleavage. We want to know more concerning the effect of different temperatures, shapes of filament cross section, degree of purity of the metal, current wave shape, etc., before passing judgment upon these remarkable phenomena of surface disintegration. Articles

like Mr. Hering's assist by stirring up curiosity and ventilating information.

(Referred to in §§ 170, 208, 223, 224, 228, 229.)

XXIII

(A passage from Chapter I, Part V, of "The New Knowledge," by Robert Kennedy Duncan, Professor of Industrial Chemistry in the University of Kansas. The A. S. Barnes Company. Printed with the permission of Professor Duncan.)

We discover that there exists in nature a certain well-known "element," uranium. This element is radioactive; that is, it has the power of continually emitting rays. These rays are of two kinds: one, the positively electrified and slightly penetrating alpha-rays, and the other the highly penetrating and negatively electrified beta-rays.

By methods of chemical fractionation somewhat similar to that by which radium is isolated from pitchblend, it has been found possible to separate from this uranium another substance altogether; and, furthermore, it turns out that this separated substance is entirely responsible for the beta-rays of the original uranium, the substance from which it was extracted giving rise only to the alpha-rays. The extracted substance is known as uranium X. This fact is followed by another. The extracted uranium X gradually but completely loses its power of emitting the beta-rays, and at such a rate that half of it has disappeared in about twenty-two days; while, on the contrary, the uranium from which it has been extracted regains this power at the very same rate, and eventually becomes as potent as ever. After it has been restored, you may, if you like, extract a second quantity of uranium X, and a third, and a fourth, and so on, as far as it is known, *ad infinitum.* This is a matter of fact into which no theory enters. On the basis of this fact, then, we seem compelled to conclude that the uranium is continuously manufacturing from itself another substance, uranium X, which has only a transitory existence; and that the power of emitting these penetrating rays, which an ounce of uranium compound at any time possesses, is due simply to the uranium X existing therein, the quantity of which depends on a balance between the rate at which it decays and the rate at which the uranium manufactures it.

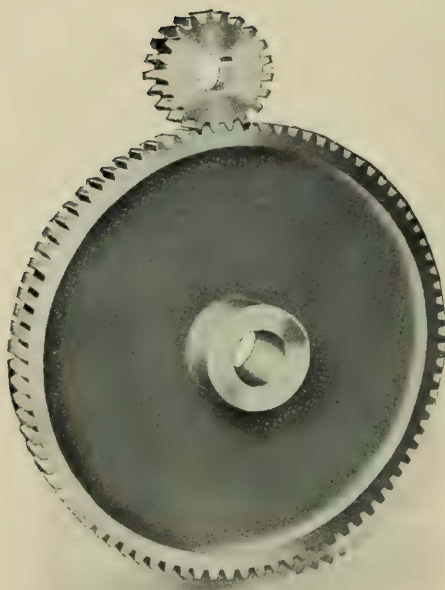


FIG. 1. — Involute Spur Gearing.

We may attempt to illustrate this mechanism by constructing a crude analogy.

Let us suppose that we have a full-grown sweet-pea vine, and that the vine is the uranium.

The tendrils of the vine are the alpha-rays from uranium.

The flowers are uranium X.

The scent of the flowers are the beta-rays from uranium X.

Let us suppose, moreover, that we leave the vine strictly alone. We can easily see that there will come a time in our garden when the flowers of the vine will decay as fast as the vine produces them, and that the total number of flowers on the plant will depend upon a balance between their rate of growth and decay. Similarly, there comes a time with the uranium when the amount of uranium X produced decays as fast as the uranium produces it, and the total amount of uranium X in the uranium depends upon a balance between its rate of growth and decay. If we were working with our flowers in the dark, as we are, metaphorically speaking, with our uranium, we might estimate their number by picking them out by their scent; we *do* estimate the amount of uranium X formed by the amount of its beta-rays. Now, let us suppose that some dewy morning we snipped off every flower; in other words, suppose we extract the uranium X from the uranium. We now have the flowers with their scent in one hand, and the uranium X with its beta-rays in the other. There remains the destitute vine with its tendrils and the destitute uranium with its alpha-rays. The flowers with their scent decay in our hand; so does the uranium X with its beta-rays. But the vine begins at once to restore its flowers with their scent, and soon has as many as before; so does the uranium soon restore its uranium X with its beta-rays. We must not be misled by our analogy: the plant produces its flowers by growth, the uranium its uranium X apparently by decomposition.

(Referred to in §§ 180, 200, 208.)

XXIV

The Involute Gear Simply Explained

(Published by The Fellows Gear Shaper Co. Printed with the permission of the publisher.)

We are all liable to have delusions about this gear problem. We may think it so complicated and abstruse that no one short

of a college professor can tackle it; or we may go to the other extreme and imagine that there is little difficulty in laying out and forming gear teeth of suitable shape for practical use. As usual, the truth lies between the two extremes.

It must be admitted that there is no machine shop problem into which we may dive so deeply as into this problem of gearing. Very fortunately, however, we can get far beneath the surface, and return to the top again with much curious and profitable information, even though we have no more complicated diving apparatus than common sense and a knowledge of everyday arithmetic. Common sense alone, without the arithmetic, will almost do for the understanding of the following paragraphs, if the writer has made the description as simple as he has tried to make it.

Statement of the Spur Gear Problem

The problem which is solved by the use of correctly made spur gearing may be stated thus: —

Let it be required to connect two parallel shafts, so that one of them will drive the other in the opposite direction smoothly, and at a definite velocity ratio.

Suppose, for the sake of illustration, that these two shafts are 35 inches apart, that the driving shaft runs at 100 revolutions per minute, and that we wish the driven shaft to run at 150 revolutions per minute, or half as fast again.

The first suggestion that would occur is the use of pulleys and a crossed belt, as shown in Fig. 2. If we make the pulley on the driving shaft half as large again as that on the driven shaft (in Fig. 2 these diameters are 36 inches and 24 inches respectively), the problem is solved, provided the diameters are *exactly* right, and there is no slip of the belt. Other combinations of diameters could have been used, of course, such as 30 inches and 20 inches, 33 inches and 22 inches, etc. Any combination in which the driver is half again as large as the driven pulley will do, providing the pulleys are not so large as to more than fill the allotted center distance.

Another suggestion is shown in Fig. 3, where rolls are used, driving each other by frictional contact. The driving roll must be half as large again as the driven roll, to give the desired velocity ratio; and the sum of the diameters of the two rolls must be such that, when they are firmly pressed into contact, the shafts will remain at the desired center distance. For a

center distance of 35 inches, the diameters must evidently be 42 inches for the driver and 28 for the driven roll. As in Fig. 2, the diameters must be exactly right, and there must be no slip. Unlike Fig. 2, however, we have in this case no other combination of diameters which will do. To have a driver half as large again as the driven roll, and to exactly fill the center

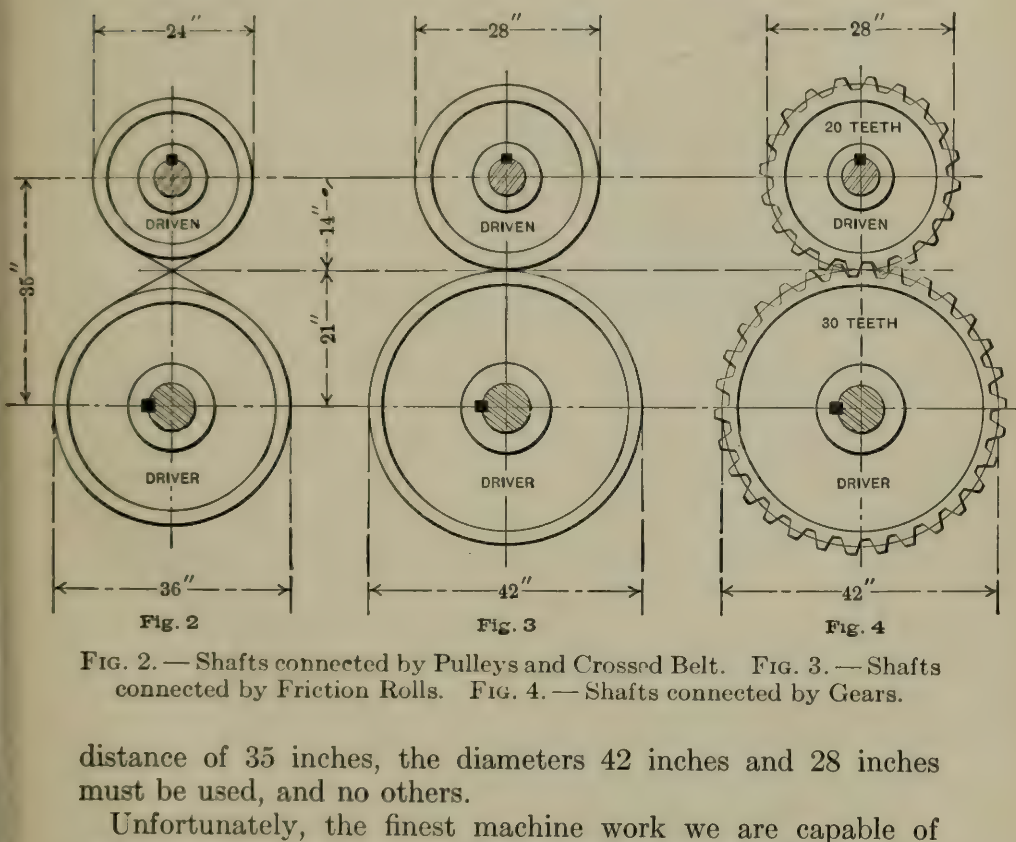


Fig. 2. — Shafts connected by Pulleys and Crossed Belt. Fig. 3. — Shafts connected by Friction Rolls. Fig. 4. — Shafts connected by Gears.

distance of 35 inches, the diameters 42 inches and 28 inches must be used, and no others.

Unfortunately, the finest machine work we are capable of will not make the diameters of the pulleys and rolls in Figs. 2 and 3 so accurate that the shafts will not get out of step somewhat in the course of a day's run at high speed. And even if we could make them accurate enough, a little overload on the driven member will cause it to slip. No dependence can be placed on frictional contact for positive driving.

The most reasonable solution of the problem we have set ourselves is, therefore, that shown in Fig. 4, where the rolls of Fig. 3 have been provided with teeth — half as many again in the driving as in the driven member. In the case shown, 30

teeth are used for the driving member and 20 for the driven member. The rolls have now become gears; and by means of them we are enabled to drive the shafts at the desired speed ratio, with no possibility of slipping.

Now in Fig. 4 we have obtained positiveness of motion, but there is danger that we may have overlooked another consideration of the problem — smoothness of motion. Figs. 2 and 3 gave satisfactory results in this particular; but in Fig. 4, unless we are careful to give just the right shape to the teeth, the driven gear will move with a jerky, irregular motion, no matter how smoothly the driving shaft is rotated.

The problem of gearing, then, becomes that of making the teeth of such shape that they will transmit motion smoothly. In modern machine shop practice that problem has been solved by using involute curves for the tooth shape; and it is to a study of the involute curve that we will now address ourselves.

The Involute Curve

What is an involute? Figure 5 answers this question. Cut a circle out of a stiff card, and tack it to the drawing board. In

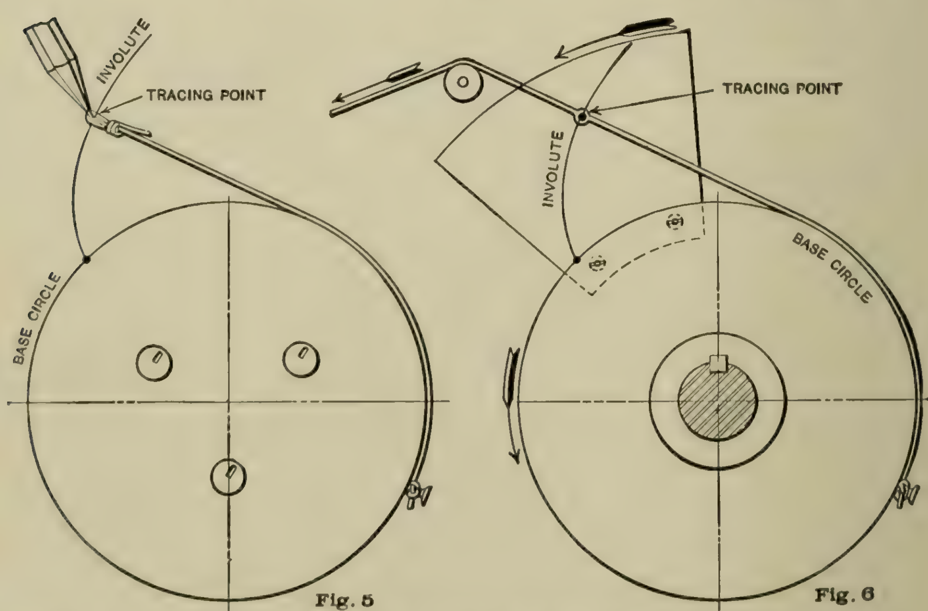


Fig. 5. — The Simplest Way of Drawing the Involute, using a Circular Card, Thread, and Pencil. Fig. 6. — Drawing the Same Involute on a Card attached to a Revolving Disk.

the edge of the circle stick a pin. Attach a thread to the pin, with a loop in the other end. Wind the thread about the circular edge of the card, stick a pencil point in the loop, then unwind the thread with the pencil, keeping it stretched taut. If the pencil point is kept pressed to the paper meanwhile, it will describe an involute on the board.

A second method is shown in Fig. 6. Here we have a disk mounted on a shaft, in place of the circular card in the previous case. Attached to the side of this disk is a segment of cardboard, as shown. The thread is wound about the disk as before, but is made long enough to run over a guiding pulley. Now stick a pencil point through the thread at any convenient place, and revolve the disk by pulling the thread. If the thread is kept taut, the pencil will then trace an involute curve on the cardboard segment.

If the diameter of the disk in Fig. 6 is the same as that of the cardboard circle in Fig. 5, the curves traced in the two cases must be identical, since both of them have been traced by points in threads which unwound from circles of the same diameter.

The circles from which these involute curves were unwound are called the "base circles." The diameter of the base circle evidently determines the involute. Involutes generated from the same diameter of base circle must be identical.

Transmitting Rotary Motion through Involute Curves

Let us see how we can apply these involute curves to the gear problem. Suppose we take the lower pulley of Fig. 2 and attach a card to its face. Let us then attach a thread or cord to its outside diameter, bringing it up around the upper pulley, and attaching it there also, as shown diagrammatically in Fig. 7.

Now if resistance is applied to the lower pulley, so as to keep the thread taut, and if the upper pulley is turned in the direction of the arrow, the two pulleys will be revolved together smoothly, and a tracing point in the thread will draw an involute curve on the card, with the diameter of the lower pulley as a base circle. The action is evidently the same as that in Fig. 6.

In the same way we may attach a card to the face of the upper pulley. If the two pulleys are rotated as before, keeping the thread taut, the same tracing point in the thread will generate

an involute on the card, having the diameter of the upper pulley as a base circle.

Next take a sharp knife, and carefully cut out the two cards along the involutes that have been drawn on them. Then attach the templets thus made in their places on the pulleys again, as shown in Fig. 9. If the two pulleys are rotated together by

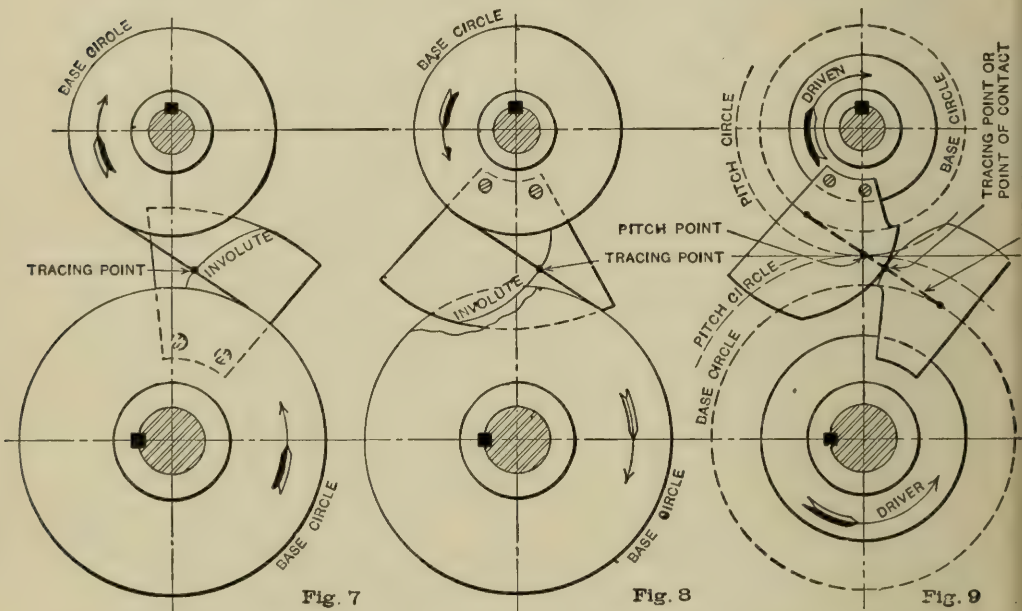


FIG. 7. — Drawing an Involute on a Card attached to the Lower One of a Pair of Disks connected by a Taut Thread, FIG. 8. — Drawing the Involute on a Card attached to the Upper Disk. FIG. 9. — The Two Cards cut out to form Involute Templets and used to transmit Uniform Motion from the Lower to the Upper Shaft.

the stretched thread, as before, the tracing point will follow along the outlines of the involute edges of the two templets simultaneously. It must be evident that both templets will be in continuous contact with the tracing point, since they were both traced by that point. They must, therefore, be in continuous contact with each other, over the whole length of the involute curves.

Now in Fig. 9 the base circles and the thread are indicated by dotted lines, since the pulleys were turned down so as not to interfere with the view of the templets. But it ought to be plain that the driving templet will transmit motion to the driven templet with just the same motion as though the connecting

thread were still there — that is to say, with just the same steadiness of motion as given by the pulleys and crossed belts. Note that the thread represents one side of the crossed belt in Fig. 2.

Two involute curves, then, will transmit steady motion from one shaft to another; and this motion may be of any desired velocity ratio, this ratio being the same as if the base circles of the involutes were pulleys connected by a crossed belt as in Fig. 2.

In Fig. 9 the straight portion of the thread, between the two base circles, is called the "line of action," because it is along this line that the contact takes place. The point where the line of action crosses the center line of the two shafts is called the "pitch point." Circles drawn through this point from each shaft center are called "pitch circles." These circles represent the friction rolls of Fig. 3, on which the teeth of the gears in Fig. 4 are formed.

That the pitch circles always make contact at the pitch point could be proved by a little elementary geometry, but a glance at Figs. 2, 3, and 4 should make geometry unnecessary. Note that the points where the belts cross the center line in Fig. 2 are the same as the point where the friction rolls make contact in Fig. 3. This will always be found to be true where the center distance and velocity ratio are the same for both cases. The crossed belts of Fig. 2 evidently, then, locate the pitch circles of Fig. 4, as the line of action and pitch point locate those circles in Fig. 9.

Since the diameters of the rolls in Fig. 3 were determined by the center distance and the velocity ratio, the pitch diameters in Figs. 4 and 9 are likewise determined. For a given center distance and velocity ratio there can be but one set of pitch diameters. But since in Fig. 2 a wide range of choice in diameters of pulleys is allowed, so in Fig. 9 any number of combinations of base circle diameters could have been used. The requirements are that they shall be in the desired ratio and shall not be larger than the pitch circles. A thread stretched from one to the other of any pair of base circles so chosen, will always be found to pass through the same pitch point, where the pitch circles touch each other.

Using the Involute for Gear Teeth

We have shown that the curved templets of Fig. 9 will transmit smooth, uniform motion, but only for a small angle of rotation. In order to transmit continuous rotary motion, there must be a new pair of involutes ready to take up the work as fast as the previous pair goes out of contact. This has been done in Fig. 10, where the involutes are applied to both faces of all the teeth in a pair of gears. By having involute faces on both sides of the teeth, the gears will run in either direction.

In Fig. 10, for variety's sake, the driving gear is supposed to run three times as fast as the driven gear, so that the latter must have three times as many teeth as the former. There are 12 teeth in the driver, and 36 in the driven gear. The pitch circles are also made in the same ratio of 3 to 1, and of such diameters that they just fill in the required center distance, whatever that may be. The base circles must, of course, have the same ratio. All this is explained in connection with Figs. 2, 3, and 4. The pulleys (base circles), crossed belts (lines of action), and friction rolls (pitch circles) of those illustrations will readily be recognized in Fig. 10.

The pitch circle of the small gear is accurately stepped off into 24 equal divisions — one for each of its 12 teeth and 12 spaces. In the same way the pitch circle of the larger gear is spaced off into 72 divisions for its 36 teeth and 36 spaces. Since the pitch diameter and pitch circumference of the 36-tooth gear is three times the pitch diameter and pitch circumference of the small gear, it is evident that each tooth division on one gear will accurately fit the corresponding space division on the other, and *vice versa*.

The height of the teeth in each gear having been decided on, involutes are drawn through the division points on each pitch circle, extending from the base circle to the top of the tooth. These form the acting surfaces. The tooth outline below the base circle in each tooth space must be so formed that it will not come into contact with the point of the mating tooth. There can be no possibility of involute action, and therefore no true involute contact, below the base circle from which the involute is generated. This is a point which mechanics sometimes lose sight of in discussing gearing questions.

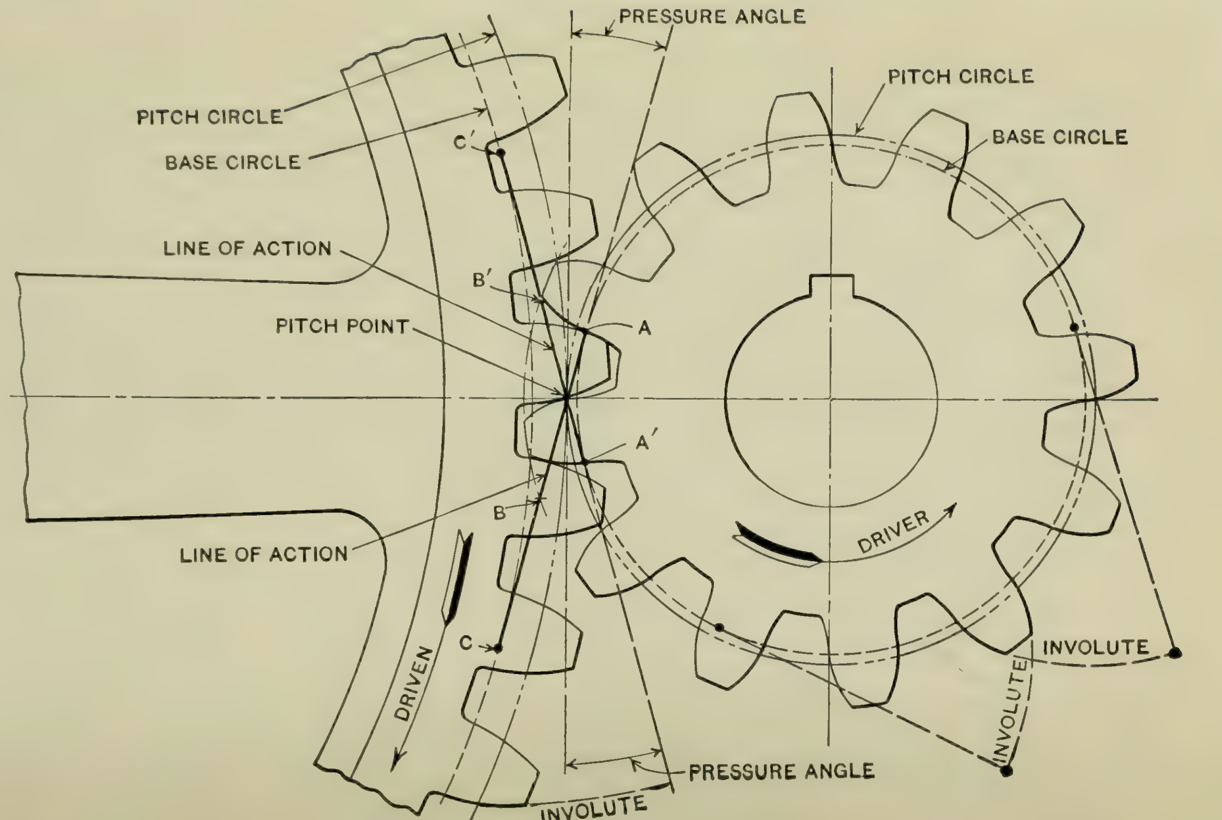


FIG. 10.—A Pair of Spur Gears whose Acting Tooth Surfaces are formed from Involute Curves determined as shown in Figs. 7, 8, and 9.

The Line of Action

As in Fig. 9, the action or contact of the tooth curves in Fig. 10 will take place along the lines connecting the base circles, and representing the imaginary crossed belts or taut thread. As in Fig. 9, also, other diameters of base circles might have been used, in which case the lines of action would have passed through the pitch point at a different angle, and teeth of a different form of involute would have resulted.

With the driving and driven gears running in the direction shown by the arrows, contact will be along the line of A-C, though not for its full length. It will begin at A, where the involute starts, and end at B, where the top of the tooth of the small gear crosses the line of action. If the driver is turning in the opposite direction, action or contact between the tooth surfaces will begin at A' and end at B'.

In Fig. 11 the case is somewhat different. Here the contact is limited both at beginning and end by the outside circles of the mating gears; it begins at A and ends at B going in one direction, or begins at A' and ends at B' in the other. In the case of the two 12-tooth gears in Fig. 21, on the other hand, the base circles limit the contact in both directions; the contact is from A to B and from A' to B'. The relative diameters of the base circles and outside circles in the different gears determine which shall limit the action.

Definitions of Gearing Terms

It will be convenient at this point to define the terms we have made use of so far, and to explain a number of the new terms and dimensions we will have occasion to use in succeeding paragraphs. These terms and dimensions are, for the most part, illustrated in Figs. 11 and 12.

The *center distance* of a pair of gears (not illustrated) is, of course, the distance between the centers of the shafts on which they are mounted.

The *velocity ratio* of a pair of gears (not illustrated) may be expressed as the ratio of the number of revolutions which the driving gear makes per minute to the number which the driven gear makes in the same time. Thus, if the driving gear runs 150 revolutions per minute, and the driven gear 82 revolutions per minute, the velocity ratio is 150 to 82. The velocity ratio

in Figs. 2, 3, and 4 is 150 to 100, or $1\frac{1}{2}$ to 1, which is the same thing. The diameters and number of teeth must be in the same ratio.

The rule for finding the velocities when the number of teeth is known is as follows: "To find the revolutions per minute of the driven gear, multiply the revolutions per minute of the driving gear by the number of its teeth, and divide by the number of teeth in the driven gear."

The *pitch circles* (Fig. 11) of a pair of gears have the same diameters as a pair of friction rolls (Fig. 3) which would fill the same center distance and revolve at the same velocity ratio. The *pitch diameter* of a gear is the diameter of its pitch circle. The center distance of a pair of mating gears is equal to half the sum of the two pitch diameters.

The *diametral pitch* (not illustrated) of a gear is the number of teeth it has per inch of pitch diameter. To find the diametral pitch, divide the number of teeth by the pitch diameter. The pitch diameter, in turn, may be found by dividing the number of teeth by the diametral pitch.

The *circular pitch* (see Fig. 12) is the distance from the center of one tooth to the center of the next, measured along the pitch line. Divide 3.1416 by the diametral pitch to find the circular pitch.

The size of a gear tooth is designated by its pitch. The diametral pitch measurement is preferred to the circular pitch for cut gearing.

Two circles which barely touch each other without intersecting are said to be *tangent* to each other. In the same way a straight line may be tangent to a circle or to any other curve. In Fig. 11 the pitch circles of the two gears are tangent, and the line of action is tangent to the base circle of each gear. The edge of a scale, laid against the edge of a disk, is tangent to it; two disks with their edges in contact are tangent to each other.

The *pitch point* (see Fig. 10) of a pair of gears is the point of tangency of the pitch circles.

The *common tangent* (see Fig. 11) of a pair of gears is a line passing through the pitch point, at right angles to the center line. It is tangent to both of the pitch circles.

The *lines of action* (see Fig. 11) of a pair of gears are straight lines drawn through the pitch point, each at the same angle with the common tangent. They represent the crossed belts of Fig. 2. Contact can only take place along the line of action.

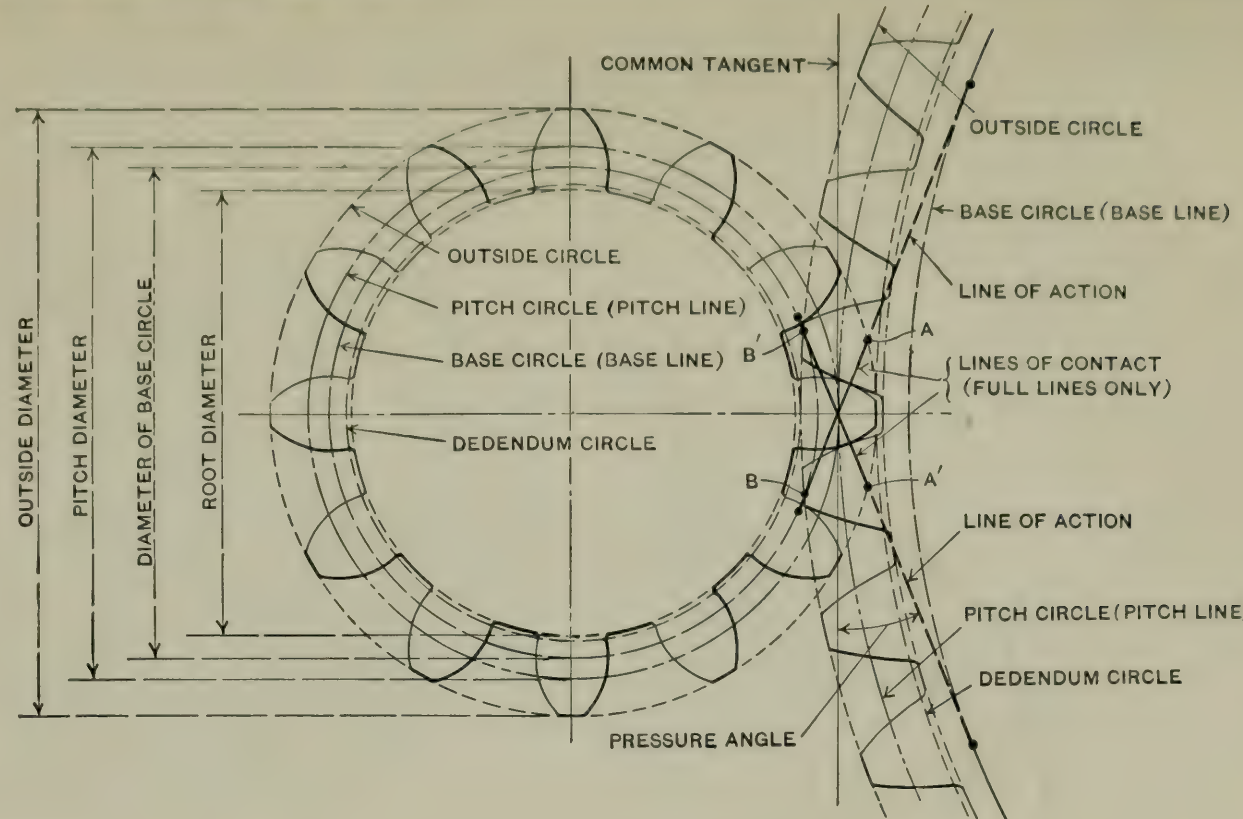


FIG. 11. — Diagram showing Definitions and Dimensions relating to Spur Gears.

The *pressure angle* (see Fig. 11) is the angle formed between the line of action and the common tangent. It was noted in connection with Fig. 10 that changing the diameter of the base circles in the proper proportion would have changed the pressure angle and the shape of the involute tooth outlines. The pressure angle is usually used to define the base circles and the tooth shape. Thus we say a $14\frac{1}{2}$ degree tooth, a 20 degree tooth, etc., when the pressure angle is $14\frac{1}{2}$ degrees or 20 degrees.

The *base circles* (see Fig. 11) are circles drawn from the center of each gear, tangent to the lines of action, and representing the pulleys of Fig. 2. They are the circles from which the involute tooth curves are developed.

The *lines of contact* (see Fig. 11) are those portions of the lines of action on which contact actually takes place. They may be limited on the one hand by the point of tangency of the line of action with the base; or, on the other hand, by the height of the tops of the teeth of the mating gear, as explained on p. 291.

An *interchangeable series* of gearing is one so designed that any gear of the set from the smallest (usually twelve teeth) to the rack, will mesh and run properly with any other gear of the same series and of the same pitch.

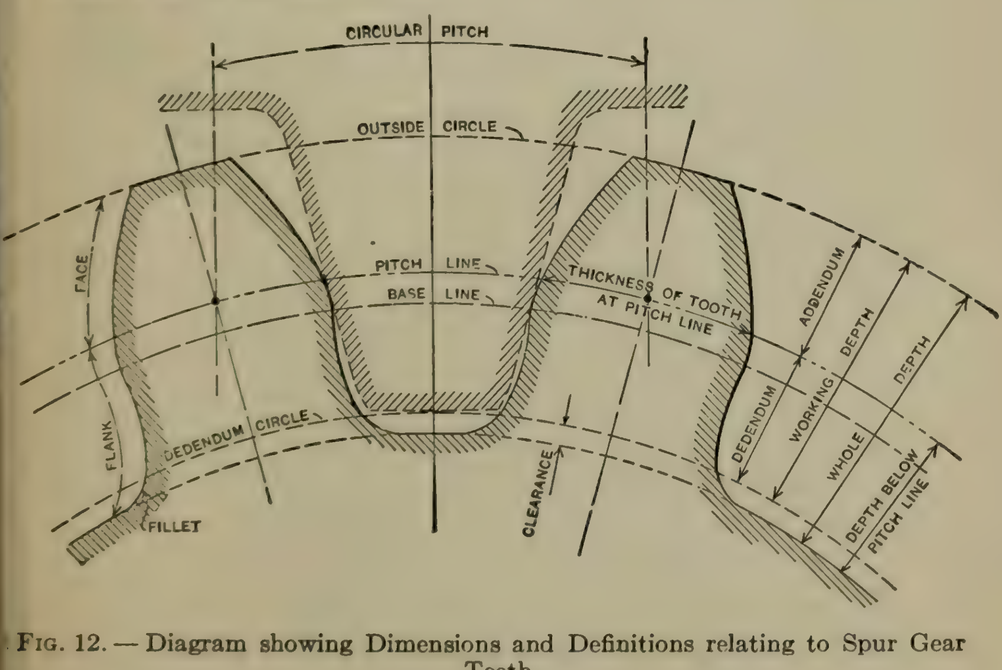


FIG. 12. — Diagram showing Dimensions and Definitions relating to Spur Gear Teeth.

The *tooth thickness* (see Fig. 12) is measured along the pitch line. It is one half the circular pitch in interchangeable gearing, and is thus equal to the width of the space. See tables in appendix.

The *addendum* (see Fig. 12) is the height of the tooth above the pitch line. In interchangeable gearing, this is the same for all gears of the same pitch. See tables in appendix.

The *dedendum* (see Fig. 12) is the depth below the pitch line to which the tooth of the mating gear extends. In interchangeable gearing the addendum and dedendum are evidently equal.

The *working depth* (see Fig. 12) is the depth in the tooth space to which the tooth of the mating gear extends. In interchangeable gearing, it is evidently twice the addendum.

The *outside diameter* (see Fig. 11) is found by adding twice the addendum to the pitch diameter. For $14\frac{1}{2}$ degree standard gears the outside diameter may be quickly found by adding two to the number of teeth and dividing by the diametral pitch.

The *clearance* (see Fig. 12) is the distance from the point of the tooth to the bottom of the space in the mating gear. See tables in appendix.

The *depth of space below the pitch line* (see Fig. 12) is found by adding together the dedendum (same as the addendum in interchangeable gears) and the clearance.

The *whole depth* of tooth space is found by adding together the clearance and the working depth. See tables in appendix.

The *root diameter* (see Fig. 11), or diameter at the bottom of the tooth space, is found by subtracting twice the depth below the pitch line from the pitch diameter.

The *face* of a gear tooth (see Fig. 12) is that part of the tooth outline which extends above the pitch line.

The *flank* (see Fig. 12) is that part of a gear tooth outline below the pitch line.

The *fillet* (see Fig. 12) is the rounded corner where the flank of the tooth runs into the bottom of the tooth space.

[The remainder of this pamphlet contains sections with the following headings:]

Standard Gear Tooth Systems

Perfect Action of Involute Gears at Varying Center Distances

Variable Pitch Diameters and Pressure Angles

The Gear Shaper Cutter as an Illustration of Involute Action

The Generating of Tooth Curves
Forming Clearance and Fillet in the Molding-Generating Process
Interference in Involute Gearing
The Relief of the Gear Shaper Cutter
The Generation of the Cutter
The Cutter Grinding Machine
Cutting Gears of Different Pressure Angles with the Same Cutter

[And the explanation ends with the following paragraph:]

Now this is only the beginning of the study of involute gearing. But we have taken up really important questions relating to the subject and discussed them without higher mathematics as promised. If it has led any mechanic to take a more lively interest in the inexhaustible study of gearing, this pamphlet has served a useful purpose.

(Referred to in §§ 155, 170, 179, 180.)

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